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Editorial

The story continues

Dear Reader

Some time has passed by since the last issue of the Scientific Journal of Orienteering. New articles are dropping in sparsely. Now, it is time for a new issue and here it is.

Initially, I hoped to find more articles to come up with new issues more frequently. In total, I’m sure that in and around Orienteering, there are so many interesting topics and questions that are not answered yet. This is reflected by the many reactions and contacts I received since the last issue.

The production of journal articles takes a considerable amount of work, time and persistence. Therefore I’m very grateful to all contributors who finalized their work so that it can be shared among all interested readers of the O-world.

Felix Arnet elaborated in his article a mathematical model to optimize route choice analysis. All active Orienteers know about the complexity of the route choice. It is not only a question of distance and climbing, but also of runability, speed, but also technical and tactical demands. Arnet integrated many of these parameters in his study and analyzed the long distance WOC competitions 2003 and 2005.

Brian Henry Parker, the chairman of the IOF Environment Commission, contributed even two articles. This may be a synonym for the importance of the work of the Environment Commission as in many countries the accessibility of Orienteering terrains are the main focus of work for clubs and organizers. Too often, in dealing with authorities, wildlife agencies and land owners, the discussion lacks of objectivity and facts. With his theoretical study on the impact of big animals on the nature in comparing to the impact of an Orienteering event, Orienteers may one more objective reason.

In the second study on breeding wheatear Parker shows in a well documented case study on a Competition in the UK, how it is well possible to arrange an Orienteering competition in an area of wildlife interests in co-work with ornithologists for the benefit of all involved groups.

Toddler’s (children between three and five years of age), are too young to compete in Orienteering as their orientation abilities are not fully developed yet. Therefore, these children are optimal to analyze the development of their orientation abilities and the influencing factors. In a large study, Elisana Pollatou and their co-workers tested 400 children in the Toddler’s age for their abilities, and, surprisingly, found no correlation to sports activities.

Mickael Blanchard and his co-workers aimed to find a parameter to quantify the physical demands of an Orienteering competition to be able to compare it to other physical efforts. Therefore, they analyzed in their study the heart-rate variability before, during and after the study. The heart-rate variability is a parameter that shows the influence and activity of the sympathetic and parasympathetical nerve system and are thought to show level of effort and fatigue. Interestingly, they found that some changes found during and after competition rely on physical activity, and others on cognitive or mental efforts. Although this article is in French, we decided to publish it here as it contains some interesting aspects for activity analysis and for future training monitoring.
Laszlo Zentai, the former chairman of the IOF Map Commission, gives a great overview on mapping techniques and the future of mapping.

Finally, I would like to welcome Scott Fraser on board the Scientific Journal of Orienteering. His help is very much appreciated. It is planned to publish a new issue by fall 2009. Therefore we would like to reiterate the importance of new contributions to the success of this journal. We look forward to receiving article submissions.

But now: Enjoy your reading!
Kind regards
André Leumann
Arithmetical Route Analysis with examples of the long final courses of the World Orienteering Championships 2003 in Switzerland and 2005 in Japan

Felix Arnet, Switzerland

Abstract
It is shown that the process of route evaluation can be done arithmetically based on vectorized map data, i.e. OCAD-Files. From this base data, a regular grid for obstruction and for height values can be derived highly automatedly. The second important part for the arithmetical route choice process is a velocity model, which determines the speed based on obstruction, ascent in run direction and slope of the terrain. Based on these three models it is possible to generate regularly spaced grid information that shows the route choices between two controls. It is possible to find different routes and to make quantitative statements about the time differences between the routes. Examples from the long final events of the World Orienteering Championships in Switzerland 2003 and Japan 2005 show the usability of the method.

Introduction
The route choice of an orienteer between two controls is mainly influenced by the distance, height differences and runnability of different routes. This information is contained in the map and the orienteer knows how to read the map to extract the needed information. Whereas distance and runnability is quite easily obtained from digital map data, the height information is contained implicitly in the contour lines. Probably because this height information is not explicit, hardly any ideas developed about the usability of digital terrain models in orienteering, apart may be from 3D-visualisation of maps.

For the WOC 2003 in Switzerland, there was a project to show 3D-animated maps and courses in the finishing areas. In order for the digital terrain model to fit contour lines of the maps, these lines were taken as the base information of the model. A methodology was developed to assign heights to contour lines of OCAD-Files in a highly automated process [2]. However, for 3D-animation purposes, continuous height model are needed, so knowing the heights of the contour lines is not sufficient. Many methods are documented to derive a continuous digital height model from contour lines. One [1] that was ready at hand was used to generate the high resolution terrain model. Because the model is based on the map contour lines, it fits them perfectly.

When I read a paper about fastest routes between observation points [4], the idea evolved to use a similar methodology to find the fastest paths between to controls. And because a high resolution digital height model corresponding to the contour lines of an orienteering map existed from the 3D-visualisation project, it was a small step to use or create all needed models (distance, height and obstruction) and apply the methodology of [4] from an orienteering point of view. However, the program [5] used in [4] offers only a restricted number of velocity models, so an own program was developed and the algorithm customized for orienteering purposes. The algorithm and found results are presented in the following chapters.

Base Data
Two bits of base information are needed to find the fastest route: First the velocity must be known at every point in every direction. Then there must be a method that finds the route from A to B, where the integrated time along the route is minimal.
Velocity Model
The velocity at a point is dependent on obstruction, slope of the terrain and the running direction. The information for the obstruction is directly contained on the orienteering map. However, the declarations are made for velocity ranges. For each kind of obstruction, one single velocity factor is used in this paper (Table 1).

<table>
<thead>
<tr>
<th>Kind of obstruction</th>
<th>Velocity range from the official orienteering map definition</th>
<th>Applied velocity factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>road, way (forest lane)</td>
<td>100%</td>
<td>1.0</td>
</tr>
<tr>
<td>Forest</td>
<td>80%-100%</td>
<td>0.9</td>
</tr>
<tr>
<td>Obstruction 20%</td>
<td>50%-80%</td>
<td>0.7</td>
</tr>
<tr>
<td>Obstruction 50%</td>
<td>20%-50%</td>
<td>0.4</td>
</tr>
<tr>
<td>Thicket</td>
<td>0 – 20%</td>
<td>0.15</td>
</tr>
<tr>
<td>Water impassable / forbidden area</td>
<td>impassable</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 1: Relationship between obstruction and velocity

The height model can be derived from contour lines [1] [2], and hence height and slope of the terrain can be computed for every point. There is no direct relationship for the velocity in dependency of slope and running direction. Commonly known may be the coarse estimate that 100 m of ascent correspond to approximately 1 km of horizontal distance [11]. This is described by the following formula

\[ \Delta t \cdot v_0 = \Delta d / f_{obstruction} + a \cdot \Delta h_{pos} \]

with

- \( \Delta d \) : covered distance [m]
- \( f \) : velocity factor (see Table 1)
- \( \Delta t \) : used time [s]
- \( v_0 \) : velocity [m/s]
- \( \Delta h \) : height difference in running direction [m]
- \( \Delta h_{pos} \): = \( \Delta h \) if \( \Delta h > 0 \), otherwise = 0
- \( g \) : terrain slope (= \( \tan(\text{angle of maximum ascent at a point}) \))
- \( a \) : 7, height correction factor
- \( b \) : 7.5, slope correction factor

With this formula, especially the lower velocities when running horizontally along a step slope are taken into account. The formula corresponds to the upper coarse estimate for a slope of 20% and running uphill. Otherwise, there were done no examinations about the correctness of this formula up to now. On descending routes in moderately sloped terrain, the velocity found by the formula is definitely to slow.

In principle, the formula stated at the beginning is valid:

velocity = velocity(kind of obstruction, terrain slope, ascent in running direction)

This relationship depends on further influences like person, tiredness, weather and so on.
Path Model

By knowing the velocity at any point in any direction, it gets possible to determine the fastest path from one point to another. A possible algorithm to solve this problem shall be shown here. Principally, the velocity model can be either taken to be continuous or discrete. With a continuous model, the physical law of wave propagation (Snell's law) builds the basic rule. With a discrete model, a solution can be found by applying the ideas of a minimum spanning tree.

Wave Propagation: Physically, the fastest way can be found exactly by using Snell's law. In praxis, the complexity of the velocity model with direction dependent velocities and hard interfaces (roads, obstruction) leads to a very complex model. This model could be only approximated numerically with sophisticated methods.

A discrete model is more promising to implement a working algorithm and therefore no further investigations were made in the direction of a continuous model.

Discrete Path Model: A discrete path model can be created by choosing single, discrete nodes in the running area and connecting neighboured nodes linearly. These connections are called edges. The time needed to get from a starting node to the end node, and vice versa, is calculated for all these edges. If it is assumed, that a virtual orienteer moves only along edges, the total time needed for a route is the sum of the times needed for the edges that build that route.

Now, the node closest to a control shall be used as the root of a tree. For all nodes connected to this root by an edge, the time needed to get to the node is calculated as a preliminary value. Then the node with the smallest preliminary value is determined. Its value is fixed, that means not preliminary any more, and new preliminary times are tested for all connected nodes (but the root node). If the
time \( t_a \) of the starting node A plus the time \( t_k \) needed for an edge to an ending node B is less than its preliminary time \( t_b \), the preliminary time \( t_b \) is replaced by \( t_a + t_k \) and the path to B is set to come from A. Now repeatedly, the node with the smallest preliminary time is searched. It will be fixed and all its preliminary neighbours are tested, if the time can be minimized. This procedure is continued until the node closest to the next control gets fixed. The time needed and the branch assigned in this manner describe the fastest route between consecutive controls. The procedure corresponds to the method to create a minimum spanning tree.

Figure 3 : Example of a minimum spanning tree with its root in A.

The entire administration of the node-edge-model can be simplified by choosing the nodes in a regular grid. The maximum distance error relating to any direction depends on the number of the connected neighboured nodes. This maximum error is 41\% if only horizontal and vertical neighbours are connected. It descends to 8.0\% if the diagonal neighbours are connected additionally, and it gets down to 2.7\% by connecting nodes in “knight”-distance. (see Figure 4). One step further and it gets down to 1.3\%.

Considering the uncertainties in the obstruction-, terrain- and velocity model, an accuracy of 8.0\% seems to be sufficient. But because it is a systematic error that does not get levelled out, using a higher accuracy may lead to more significant results.

![Figure 4: Maximum and average distance error in dependence of the number of edges to neighboured nodes. (See Appendix A for the formulas of maximum and average systematic errors).](image)

The denser the nodes are chosen and the more edges in different directions are considered, the better is the approximation of routes that do not run along edges. For the augmentation of the accuracy, it must be validated that the edges approximate all directions in an optimal way. Systematic errors are produced otherwise.
Data Analysis

In the first part of this chapter, different types of results of the discrete path models are presented. These types exist independently of the applied velocity model and the nodes and edges chosen in the discrete path model.

In the second part, different velocity models and neighbourhood models for regular grids are compared.

Time Model

In the time model, all the minimum times are displayed, that are needed to get from a control to any node along the defined edges. Generally, it cannot be said from the time model, which path to a point actually is the fastest.

For route analysis, the inverse time model is interesting. It shows the time needed to get from any point to a control. For the inverse model, the times in inverse direction build the costs for the minimum spanning tree. Route analysis can be carried out combining time model and inverse time model. When calculating a time model from point A and an inverse time model from point B, then the value at B in the time model matches exactly the value at A in the inverse time model. Actually, in the implemented algorithm there are some minor discrepancies due to the fact, that the slope is just considered at the starting nodes.

Direction Model

The direction model shows the last direction at every point which leads from the starting point to the respective point. By tracing back the directions, it is possible to find the fastest path. However, this is normally quite difficult to do in a visual way.

Naturally, the number of different directions is limited to the number chosen in the discrete path model (see Figure 8).

This representation is especially interesting for course setters: it shows areas where the attacking direction changes. Regions, where two or more highly differing directions exist, indicate areas, where differing routes are equally good.

The inverse direction model is interesting for course setting, too. It indicates, where from different settings lead to a control.

Route Model

An interesting model is obtained by adding the time model at a point A and the inverse time model at a point B. That means, for every node, the values of the two models are added. Then, all the nodes along the fastest path get the same value: the minimum time needed to get from A to B.

The representation shows for any point C the minimum time needed to get from A to B, when C must be part of the path. With that, the amount of units needed additionally along a specific route compared to the fastest path can be estimated. If a route differs several times from the ideal route or an alternative route, then the loss is at least the sum of the maximum differences. The entire path of an alternative route is not directly displayed. However, different routes and corresponding losses are clearly recognizable.

How to read route model images: along the fastest routes, the color is a constant red. Alternative routes are characterised by bands of constant colours, where on both sides of the band the colours "increase" (red → yellow → green → blue → purple → red → ...). On the other hand, when colour "decrease" on one side, bands of constant colour do not describe an alternative rout. The calculated time of an alternative route corresponds to the number of traversed colours to get to this route.
Figure 5: Schematic time model

Figure 6: Time model. Starting point at the control in the lower right part. The model shows the time needed to get to any point from the control. The interval of the red curves is 100 units. Hence, there are needed ≈ 2950 units to get to the control in the upper middle.

Figure 7: Inverse time model. End point in the upper middle. The model shows the time needed to get from any point to the control. The interval of the red curves is 100 units. Hence, there are needed ≈ 2950 units to come from the control in the lower right part. This value matches the one in Figure 6.
**Figure 8: Direction model.** Starting point at the control in lower right part. Red: attacking direction from east; green: attacking direction from south west; blue: attacking direction from north west.

**Figure 9: Inverse direction model.** Ending point at the control in the upper middle. Red: starting direction towards east; green: starting direction towards south west; blue: starting direction towards north west.

**Figure 10: Route model.**

a) Time model for A

b) inverse time model at B
c) Route model A - B
Testing Different Models

Velocity Models

After knowing the basic types of models, it is possible to visualize the effects of different model parameters like velocity model or neighbourhood model. The area below was chosen to compare different parameters. The goal is to find the route from the start in the right part to the control in the left part.

Figure 13 demonstrates clearly that the coarse estimate returns an optimum route which follows as much as possible a line with no ascent, even if the path lies in very steep terrain. The slope formula returns a more reasonable route along the ridge of the hill or costly alternatives descending first to the foot of the hill.

Due to the described deficiencies of the coarse estimate and the lack of another velocity model, the following considerations were all done with the slope model.

Figure 12: Model test area. With the goal to find the route from start point to control (Extract from [8])

<table>
<thead>
<tr>
<th>Route</th>
<th>F1: Coarse estimate</th>
<th>F2: Slope Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Delta t \cdot v_0 = \Delta d / f_{\text{obstruction}} + a \cdot \Delta h_{\text{pos}}$</td>
<td>$\Delta t \cdot v_0 = \Delta d / f_{\text{obstruction}} + a \cdot \Delta h_{\text{pos}} + (g \cdot g \cdot b) \cdot \Delta d$</td>
</tr>
<tr>
<td></td>
<td>$\Delta t \cdot v_0 = \Delta d / f_{\text{road}} + a \cdot \Delta h_{\text{pos}}$</td>
<td>$\Delta t \cdot v_0 = \Delta d / f_{\text{road}} + a \cdot \Delta h_{\text{pos}}$</td>
</tr>
</tbody>
</table>

Figure 13: Comparison between two velocity models.
Discrete path models

It shows that all three discrete path models lead to essentially to the same possible routes. However, the horizontal / vertical model shows some artefacts and short cuts compared to the other models. The differences between the diagonal and knight distance model are much smaller. It can be assumed, that for quality analysis of routes, both methods lead to reasonable results. The smaller systematic error of the knight distance model is an argument for this more precise model, opposed to a higher computational effort.

The grid space comparison shows the degradation of the results with increasing grid space. The differences tend to level out and small details are not recognizable any more. The fact that the slope is only considered in the starting nodes in the applied calculating algorithm leads to ever increasing artefacts, i.e. the fastest path is no longer red in the 10 meter example.

**Figure 14:** Comparison between different discrete path models.

Grid Space

The grid space comparison shows the degradation of the results with increasing grid space. The differences tend to level out and small details are not recognizable any more. The
Discussion of Examples

The analyses presented here were realized using the slope velocity model of chapter ‘velocity model’ and a discrete path model. The nodes of the path model were chosen in a regular grid spaced 1 m and edges to neighbours in knight distance were considered. The velocity model to calculate the time needed along an edge was simplified such that the mean obstruction along each edge was taken and only the terrain slope at the starting node was considered.

The examples show route choice problems given to the runners at the long final competitions at WOC 2003 in Eschenberg, Switzerland and at the WOC 2005 in Tomoeyama, Japan.

Apart from selected route choice problems, complete route data of the top nine runners in Eschenberg, both men and women, were available for further verification of the applied velocity model.

Men WOC 2003

Over all analysis

For the verification of the velocity models, the times of the top nine men for each control were compared with the needed number of units along their routes, calculated with the slope velocity model. The goal was to find routes, where the velocity model tends to be too slow or too fast.

For this purpose, the ratios between units and time were calculated and then normalized such, that they were divided by the total ratio of...
each runner. Finally, the mean normalized ratio of the top nine men was determined for each control (see Table 1):

t_i: time of runner r from control i-1 to i

u_i: units of runner r from control i-1 to i

according to his route and velocity model

r_i: ratio between units and time from control i-1 to for runner r: \( \frac{u_r}{t_r} \)

n_i: normalized ratio of runner r from control i-1 to i: \( \frac{u_r}{t_r} / \frac{\sum_i u_i}{\sum_i t_i} \)

m_i: mean normalized ratio from control i-1 to i: \( \frac{\sum_r n_r}{\sum_r 1} \)

<table>
<thead>
<tr>
<th>Control</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tbody>
<tr>
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<td>0.92</td>
<td>0.98</td>
<td>1.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Mean normalized values of the top nine men. A value > 1.1 indicates a too slow velocity model, a value < 0.9 a too fast model.

Figure 16: WOC 2003. Long final men in Eschenberg, route 3-4, from middle right part to middle left part. One traverse red \( \rightarrow \) red corresponds to time to run 256 m on flat road. Drawn routes: red: Tom Bührer (tb); purple: Juri Omeltchenkow (jo); blue: Emil Wingsted (ew); red dashed: selected others
Without documenting here each route, it shows that in steep terrain, the routes run more or less perpendicular to the contour lines, the velocity model is too slow. Most extremely this shows to control 6, a very short route down a steep slope to the river valley. This indicates that the slope correction component could be improved significantly.

On the other hand, the model tends to be too fast for routes with a high component of cross running. This indicates that road running probably should have a higher velocity factor than 1.

**Selected routes**

Route 3-4 (Figure 16): The calculated routes correspond approximately to the actually chosen routes. Also the qualities correspond to really lost times.

<table>
<thead>
<tr>
<th></th>
<th>TB</th>
<th>JO</th>
<th>EW</th>
<th>CJ</th>
<th>MM</th>
<th>BV</th>
<th>JL</th>
<th>HJ</th>
<th>MJ</th>
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<tbody>
<tr>
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<td>720</td>
<td>752</td>
<td>781</td>
<td>724</td>
<td>808</td>
<td>771</td>
<td>775</td>
<td></td>
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<tr>
<td>units</td>
<td>4100</td>
<td>3924</td>
<td>3951</td>
<td>4182</td>
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<td>4.88</td>
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</tr>
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<td>1.19</td>
<td>1.10</td>
<td>1.09</td>
<td>1.13</td>
</tr>
</tbody>
</table>

**Table 2: Time and units for routes.** From control 3 to 4. Abbreviations: TB: Tom Bührer; JO: Juri Omeltchenkov; EW: Emil Wingstedt; CJ: Carsten Jørgensen; MM: Mikhail Mamleev; BV: Björnar Valstad; JL: Jani Lakanen; HJ: Holger Hott Johansen; MJ: Michal Jedlicka.

**Figure 17: WOC 2003.** Long final men in Eschenberg, route 21-22, from right lower part to upper middle part. One traverse red → red corresponds to time to run 256 m on flat road. Drawn routes: red: Tom Bührer (tb); purple: Juri Omeltchenkow (jo); blue: Emil Wingstedt (ew); red dashed: selected others.

Route 21-22 (Figure 17): The first part of the route corresponds to the actually fast route of Tom Bührer. The direct path of the second part was not chosen by any competitor, but the gully was surrounded further along the road and then continued along the greenish route coming from uphill. This route is calculated to be a bit slower than the route crossing the hill. The actually reached times however classify the route crossing the hill as slower (Bührer ↔ Wingstedt). This is an indication that the slope in the velocity model is weighted to low.

Interesting alternative routes are recognizable on the left side.
Table 3: Time and units for routes from control 21 to 22.

<table>
<thead>
<tr>
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<th>EW</th>
<th>CJ</th>
<th>MM</th>
<th>BV</th>
<th>JL</th>
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<td>1.06</td>
<td>1.10</td>
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</tr>
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</table>

Table 4: Time and units for routes from control 24 to 25.

<table>
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<th>JO</th>
<th>EW</th>
<th>CJ</th>
<th>MM</th>
<th>BV</th>
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<td>0.92</td>
<td>0.94</td>
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</table>

Women WOC 2003

Over all analysis

The mean normalized values of the top ten women (see Table 5) show the same tendencies as the ones of the men:

modelled velocities along cross routes are too high, and modelled velocities are too slow in very steep area.
Table 5: Mean normalized values of the top ten women. A value > 1.1 indicates a too slow velocity model, a value < 0.9 a too fast model.

<table>
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<tr>
<th>Control</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>1.15</td>
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<td>0.89</td>
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</table>

Selected routes

Figure 19: WOC 2003. Long final women in Eschenberg, route 2-3, from middle right part to middle left part. One traverse red $\rightarrow$ red corresponds to time to run 256 m on flat road. Drawn routes: red: Simone Luder (sl); blue: Karolina Arewang Höjsgard; purple: Brigitte Wolf (bw); red dashed: selected others

Route 2-3: The route choice is similar to the men’s 3-4. Compared with the men’s, the routes along the river valley are calculated as much slower. On the other hand, the routes crossing the village on the hill seem to be much more attractive and connected to an only minor time deficiency. However, it was not chosen by any of the top ten women.
Table 6: Time and units for routes from control 2 to 3. Abbreviations: SL: Simone Luder; KA: Karolina Arewang Höjsgard; BW: Brigitte Wolf; EE: Emma Engstrand; SG: Sara Gemperle; BB: Barbara Bazcek; HS: Hanne Staff; MA: Marianne Andersen; KS: Karin Schmalfeld; MB: Martina Rakayewa

<table>
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<tr>
<th></th>
<th>SL</th>
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<th>BW</th>
<th>EE</th>
<th>SG</th>
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Table 7: Time and units for routes from control 10 to 11.

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<td>1.00</td>
<td>0.96</td>
<td>1.00</td>
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Figure 20: WOC 2003. Long final women in Eschenberg, route 10-11, from lower left part to upper middle part. One traverse red arrow corresponds to time to run 256 m on flat road.

Route 10-11: The route model has no problems in finding fire roads and small passages between obstruction, and it assumes that the velocity in clearings and on fire roads is good or very good. Therefore, there appear routes on the left hand side, that are computed to be faster than the often chosen, safe greenish route on the right hand side. The second part of the fastest route was approximately chosen by some competitors (Luder, Bazcek). For the first part, the runners preferred the hardly slower route along the road to the more difficult and uncertain direct route.

Men WOC 2005

For this paper, the routes of neither men nor women courses were known but for the top three runners. These again often took similar route choices, so that systematic examinations were not possible. However, described routes and times in [6],[9] and [10] indicate that the arithmetic route choice does a fairly good job in evaluating the quality of routes in the Tomoeyama terrain.

Route Start-1 (Figure 21): Already the first control of the men's course shows an abundance of routes. It is very similar to the women's first route choice problem and almost all computed routes were run.
Figure 21: WOC 2005. Long final men in tomoeyama, route from start to 1.

Figure 22: WOC 2005. Long final men in tomoeyama, route from 10 to 11.

Route 10-11 (Figure 22): The first long route choice problem. Khramov and Lauenstein took the route left hand route (in running direction, blue), and were a minute slower than David Schneider, who took the right hand route (red).

Route 14-15 (Figure 23): All known runners took the direct line from control to control. Smaller or larger deviations to the south as indicated by the arithmetical algorithm were not tested.

Route 16-17 (Figure 24): The calculated fastest route runs along the main ridge to the west and then quite straight to the south. The first part, to the big road, was chosen by Khramov and Lauenstein. They then continued further along the road and run along the hill that leads to the control. They were about as fast as David Schneider, who followed more or less the green route on the eastern side. The route choice problem from the big road to the control was quite similar to the second part of the women's problem from control 8 to 9. There, Simone Niggli and Heli Jukkola took the direct route (red) and were about 40 sec faster than Vroni König, that chose the same route as Khramov.
Women WOC 2005

Route 5 to 6 (Figure 25): The solution to the runners seemed to be more obvious to the runners than it seems from the calculated one: All known runners took the fastest route.

Route 8 to 9 (Figure 26): The problem is a reduced one of the men’s route choice from 16 to 17. As mentioned before, the red route actually is also the fastest route found according to the time needed.

Route 10 to 11 (Figure 23): A far larger choice of equivalent routes is found by the arithmetical analysis than probably most of the runners were aware of. The route along road is calculated as competitive, because no steep slope correction factor is applied on roads (see F2).

Route 13 to 14 (Figure 28): Heli Jukkola and Vroni König took both the (red) route along the ridge and were about 40 sec faster than Simone Niggli, who chose the alternative along the road (purple).
Conclusion

Computer assisted route analysis is capable to show possible routes between two controls. This has been demonstrated for the long final events of the WOC 2003 and WOC 2005. Some assumptions in the velocity model concerning the relationship between the velocity and the slope of the terrain may be improved. For this, more systematic tests are needed. The results of such research would also be otherwise interesting information for orienteers. Another possibility may be to calibrate the model from actually run routes. The direction model shows interesting information for course setter where to find route choice problems. Though there are a lot of other factors to consider for a route choice that are neglected in this arithmetical analysis, the comparison with other experiences may lead to conclusions for criterions of routes choices.

Acknowledgements

Thanks to all people that were readily giving me their data for this paper. Especially to Shin Murakoshi, who provided the OCAD-Map of Tomoeyama to me for this analysis.

References


Appendix A

Deduction of the average distance error

From Sinus theorem:
\[ \frac{a}{\sin(\phi_0)} = \frac{b}{\sin(\phi)} = \frac{c}{\sin(\phi_0 - \phi)} \]
\[ \phi_0: \text{angle between consecutive edges}, \ \phi: \text{angle random direction between 0 and } \phi_0 \]
\[ a: \text{line in direction of } \phi; \ b,c: \text{lines along edges used to approximate a} \]
\[ (b + c)/a : \text{distance error in direction } \phi \]

\[ \text{Average distance error } = \int_{\phi_0}^{0} \frac{(b + c)/a}{\phi_0} \ d\phi \]

\[ \phi_0 = (2 - 2\cos(\phi_0))/\phi_0 \]

The values are for \( \phi_0 = \pi/2; = \pi /4; = \pi /8; \)

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A physical model for comparing the trampling impact of large grazing mammals and off-track recreational activities

Brian Henry Parker
From the Environment Commission, International Orienteering Federation

Abstract
A simple model, based on physical principles, is proposed for calculating the relative trampling damage of recreational activities compared with that from large grazing mammals in the terrain. Use of the model for a case study of a large orienteering event suggests that the impact of the event would be negligible compared with that from a single grazer, this result arising from the very much greater time in the terrain spent by the grazer.

Introduction
In the absence of objective data on the trampling impact on soils and vegetation by off-track recreational activities, such as orienteering, relevant to the areas under their control, land managers and ecologists have to use subjective judgement about the acceptability of the activity. For large orienteering events, for example, with more than 1000 participants, there is a common perception that there is potential for widespread unacceptable levels of vegetation trampling. In such circumstances the land managers may refuse access as an environmental precautionary measure.

However, it may be possible to gain an insight into the potential trampling impact of the off-track recreational activity specific to the terrain in question, if there are large grazing mammals present. This paper offers a simple physical model for comparing the trampling impact of a large grazing mammal with that of a recreational human being. Land managers can make objective judgements about the level of acceptability of the trampling damage from the grazers and relate this to the expected level of damage from the recreational activity as calculated by the model.

Physical Model
The prime variable in damage to vegetation by trampling is considered to be the underfoot pressure (Cole and Bayfield (1993), Liddle (1997), Chapter 2). Although low forces and pressures may not be damaging, due to the elasticity of plant material, once the elastic limit is exceeded, as occurs with human and large mammal trampling, damage results. The relationship between pressure and damage is considered to approximate to linearity over the range comparing man and large mammals.

The second variable is the number of foot placements. Provided the foot placements affect undamaged vegetation, a reasonable starting assumption, this variable will also be linear. The physical relationship between damage and the two variables is then:

\[
\text{Damage} \propto \text{Underfoot pressure} \times \text{No of foot placements}\]

The number of foot placements is given by the average stepping rate and the length of time that the subject is moving across the terrain. The relationship revises to:

\[
\text{Damage} \propto \text{Underfoot pressure} \times \text{Stepping rate} \times \text{Time in motion}\]

In comparing the impacts of man and large quadrupeds the underfoot pressure exerted whilst moving in the terrain depends on the weight of the subject and the number of feet in contact with the ground. For a walking and running human the weight is essentially carried on one foot at any one time. For a large mammal the matter is more complex. If walking slowly, such as when grazing, there are three
feet in contact with the ground at any one time. If moving with a brisker purpose, it has only two feet in contact with the ground at any one time (Gray 1953).

The relationship 1.2 becomes:

\[ \text{Damage } D \propto \left( \frac{W}{n \cdot A} \right) \times s \cdot T \]

where \( W \) = the weight of the subject;
\( A \) = underfoot area for each limb;
\( n \) = the number of feet in contact with the ground whilst moving (\( n = 1 \) for human; \( n = 3 \) for a grazing mammal);
\( s \) = number of steps taken per unit time;
\( T \) = time moving about the terrain

The damage (D) may be any of a number of indicators, such as the area affected or the mass of material showing signs of impact. The relationship 1.3 could be converted to an equation, were the constant of proportionality known. However, if it is assumed that the constants of proportionality are broadly similar for grazing mammals and man for a given damage indicator, then an equation comparing the trampling damage of a large grazer (g) with that of a human (h) can be established:

\[ \frac{D_g}{D_h} = \frac{[(W/3 \cdot A) \times s \cdot T]_{\text{grazer}}}{[(W/1 \cdot A) \times s \cdot T]_{\text{human}}} \]

An example of the practical use of Equation 1.4 is given in the following case study.

**Case study of Braunton Burrows Biosphere Nature Reserve**

The Braunton Burrows Nature Reserve covers a coastal sand dune area in the South West of England near the town of Barnstaple. The 12 km² site contains a number of rare plants and has high conservation status, as indicated by the ‘biosphere’ designation. It might be expected that conservation management of a nature area of such importance would exclude public access or, at least, restrict access to designated routes or walkways. However, the site is unusual in that it has been used for military training since the early part of the last century. Access by the military is mostly on foot but there is also movement by specialised terrain vehicles. In view of the continued military use the landowners also permit casual public access.

In one important respect the military and public access to the area is beneficial to the ecology of the site. This is in assisting the maintenance of bare sand cover, essential for the survival of certain species, such as the rare Great Sea Stock *Matthiola sinuata*, which requires a shifting sand habitat. Therefore, the UK government nature advisory body which oversees the conservation of the site accepts that the military and casual public presence on the site is an unusual but essential element in its conservation management. This acceptance did not extend to additional access. In 1990 an application was made to hold a regional orienteering event with about 1000 entrants. The advisory body, then the Nature Conservancy Council, turned down the application on the grounds that the trampling damage from the event would be unacceptable.

However, it was learned that there were difficult management problems with the dune vegetation. The character of the dunes has been shaped by grazing, mostly by rabbits. Since 1954, when myxomatosis greatly reduced the population, and since reduced again by viral haemorrhagic disease, rabbit numbers have been less than 1% of their pre-1954 levels. Consequent upon the near total loss of grazing, the dunes have been progressively covered with coarse grasses and scrub to the detriment of the thyme-rich turf upon which many of the plant and animal specialities depend. Mowing the rank vegetation had taken place for many years but had not proved as effective as hoped. Instead the NCC favoured grazing by cattle and planned to introduce 200 head of moorland cattle into the dunes.

It is possible, using Equation 1.4, to compare the trampling impact of a single cow in
The terrain for one year with that from an average adult orienteer. For grazing cattle, but not for orienteers, it is necessary to make a 'lying down' correction to their time in the terrain. Vickers (2003) reports that dairy cattle require 8 hours per day for this resting purpose. It is assumed that moorland cattle exhibit similar requirements and an average of 8 hours per day is taken as the period during which the contribution to overall vegetation damage can be ignored.

A correction is also needed to take account of different stepping rates for grazing mammals and human recreationists. In order to determine approximate values for the average number of steps per unit time, the author observed grazing cattle and walkers. In the case of grazing cattle this appears to be very variable, much less so for walkers. The observations showed, as might be expected, that there are more foot placements when moving from one grazing patch to another, although there can be considerable shuffling within the grazing patch. There are also periods of stasis. Observations of moorland cattle revealed a foot placement average of 43 ± 25 steps per minute and, for walkers 87 ± 12 steps per minute.

The data to be inserted are:

For the subject weights

- Wgrazer = 500 kg;          Whuman = 75 kg;
- Underfoot areas
  - Agrazer = 65 cm²;          Ahuman = 200 cm²;
- Time in terrain total
  - Tgrazer = 8760 h (1 y);   Thuman  = 1.25 h;
- Time in terrain on feet
  - Tgrazer = 5840 h;          Thuman  = 1.25 h;
- Stepping rate
  - sgrazer = 43 min⁻¹;       Thuman  = 87 min⁻¹;

\[
D_g / D_h = \left( \frac{[(500 / 3) \times 65 \times 43 \times 5840]}{[(75 / 1) \times 200 \times 87 \times 1.25]_\text{human}} \right)
\]

\[
= 15789
\]

The calculation suggests that one cow, present in the terrain for one year, is equivalent to about 15,000 adult orienteers in terms of potential vegetation damage. For the proposed herd of 200 cattle the equivalent ratio is about 3 million orienteers.

Notwithstanding the approximate nature of the calculation and its assumptions, the conclusion that the trampling by competitors in the proposed large orienteering event was likely to be negligible compared with that of a year's grazing by a single cow, let alone a herd of 200, is convincing. The Nature Conservancy Council accepted this conclusion and withdrew their objection to the event based on trampling concerns.

**Discussion**

The case study calculation shows a very substantial difference between the damage from just a single large grazing mammal and a large orienteering event. The bulk of the difference is due to the grazers’ much greater time in the terrain, the damage rates of man and grazer being broadly similar.

The model is simple but based on sound principles of physics. A number of assumptions have been made to maintain simplicity. It is questionable whether re-examining these assumptions and improving the sophistication of the model would make any practical difference to the conclusion of the case study comparison, which is that the trampling damage from a large orienteering event is very much less than that from a single large grazing mammal. To invalidate that conclusion a factor of at least one order of magnitude would need to be produced.

There is, however, one difference between the pattern of damage by grazers and orienteers. The grazers’ interest is focussed on grazing areas, so that their trampling damage is areal. The orienteers’ interest is on moving from one control point to the next, so their trampling damage tends to be more lineal, especially in the vicinity of the control points. This can produce visible trails of marked vegetation. Such trails are temporary, effectively vanishing...
in one, two or three growing seasons, depending on the nature of the affected vegetation (Mendoza 2008).

In conclusion it is suggested that orienteering and other off-track recreations wishing to access terrain which contains large grazing mammals may find this model, and the conclusions it gives rise to, simple and effective for presenting a case to land managers.

References


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The effect of an Orienteering Event on Breeding Wheatear *Oenanthe oenanthe* at Titterstone Clee, Shropshire, UK

**Brian Henry Parker**  
From the Environment Commission, International Orienteering Federation

**Abstract**  
An orienteering event with over 1000 competitors took place over the former upland mining area of Titterstone Clee in the West Midlands of the United Kingdom on 31 May 1999. The area supports a population of about 40 breeding pairs of migrant wheatear *Oenanthe oenanthe*, which are monitored by local ornithologists. The event had no observable effect of the breeding success of the nests within the competition area. However, four nests were abandoned in the derelict quarry used for car parking and the competition centre facilities. This area had been selected for this purpose according to established good environmental practice, to minimise visual intrusion and ecological disturbance, but the propensity for wheatear to nest in such man-made terrain was unknown to the event organisers. Measures have been put in place to prevent a recurrence. Retrospective analysis of data from the orienteers and the ornithologists has quantified the levels of potentially disturbing orienteering activity near nests. It is concluded that breeding wheatear are very tolerant of transient disturbance. Similar tolerance is expected for stonechat *Saxicola torquata*, also present on Titterstone Clee.

**Introduction**  
The wheatear *Oenanthe oenanthe* is a breeding summer visitor from equatorial Africa to the United Kingdom (Štastny 1995). It is a typical bird of stony mountainsides and rocks but also found at lower altitudes in quarries and stony terrain with thin vegetation. Short turf, created by grazing animals or poor soils on steep rocky slopes is essential for feeding. Nests are made in piles of stones, rock crevices, rabbit burrows or even abandoned machinery. These conditions are found on Titterstone Clee.

Titterstone Clee is a hill rising to modest height (533m) above the lowland area of the county of Shropshire in the West Midlands of the United Kingdom (Shropshire Geology 2004). Its prominent form results from an intruded dolerite sill which caps its summit and protects the underlying limestone, ironstone and coal measures from erosion. All of these strata have been worked in the past and a large quarry extracting roadstone still operates. The hill is extensively marked with old workings, varying from exploratory scrapings, bell pits and shafts to large derelict quarries. These together form a complex terrain of interest to, amongst others, industrial archaeologists and orienteers.

The wheatear is not a UK protected species. However, it is a migrant well regarded by ornithologists for its attractive appearance, distinctive song and spectacular flight. There is particular interest in the important population of 40 or more breeding pairs on Titterstone Clee, which appears to be increasing, against a national trend of decline (Shropshire Ornithological Society 2002). The Society conducts annual detailed surveys to locate each nest and ring the young before they fledge. In 1999 a total of 46 breeding pairs were identified and their nests precisely located.

In that year an orienteering event took place on 31<sup>st</sup> May, at which time the eggs had hatched but the young were not fully fledged. The event was large, with 1173 competitors, part of a regional multi-day ‘Springtime in Shropshire’ series. Normal good practice was observed for its environmental conduct. No ecological constraints had been identified for the competition terrain and the competition centre (the car parking, general assembly and administrative area) was located in the derelict quarries to reduce visual intrusion and, by previous experience, to avoid ecological impact on flora and fauna of merit. This last intention was, not known to the orienteers at the time, to
fall short of expectation. The organising club were informed in December 1999 by the Shropshire Wildlife Trust stating that there had been a problem with the event resulting in a number of nests being abandoned.

Contact was made with the local ornithologist responsible for the Titterstone Clee wheatear survey to obtain further information. He explained that the wheatear favoured nesting in the old quarry workings and stone rubble directly bordering the verges where the event tentage had been placed and the closely adjacent continuous disturbance had prevented the parent birds from feeding their young. A survey of the area after the event showed that a total of four nests had been abandoned in these high disturbance areas. It was reported that there were no failures of nests elsewhere on Titterstone Clee although several had been in locations of high orienteering activity.

Having understood and discussed the problems that had inadvertently arisen during the event, mutual arrangements were agreed between the ornithologists and the orienteers to safeguard the viability of the wheatears at future events.

Research into the disturbance of breeding birds by orienteering events

A widespread reason for access restrictions, in space and time, on orienteering and other formal off-track activities using natural and semi-natural countryside is their potential for disturbing breeding birds and reducing their breeding success. In the United Kingdom, for example, the Chief Executive of English Nature, the then organisation responsible for nature conservation in England, stated to a government commission investigating the environmental impact of leisure activities that “the most contentious area remains disturbance of breeding birds” (Langslow 1995).

It might be expected that research into the disturbance of breeding birds is a priority. However, there is a difficulty in quantifying disturbance and monitoring its effects which results in formal studies being time-consuming and expensive. There is a preference for status studies in which populations are monitored for many seasons and the difficulty of correlation with any effects of disturbance from ephemeral activities results in an unwillingness to set up or support research into the impact on bird populations by one-off events.

There is, therefore, a dearth of scientific data on the effects of orienteering events on the breeding success of birds. A research review by the International Orienteering Federation into the ecological impact of orienteering (Parker 2005) reports only one study of merit in this field. This was conducted in Brandon Park, Suffolk, UK (Goodall and Gregory 1991) and concluded that the event had no observable effect on all 51 species studied.

When, several years after the Titterstone Clee event, it was learned that sufficient archived data could be recovered from the ornithologists and from the orienteers to allow a useful analysis of levels of disturbance, the opportunity was taken to add a further species to the list of breeding birds studied in the context of orienteering.

Retrospective analysis

The study of disturbance of breeding birds by an activity, whether conducted in real time or, as in this case, analysis of historical data, requires reliable information about the birds and about the levels of disturbance during the activity.

The necessary requirement with respect to the birds is that specific individuals are monitored before and after the activity to determine whether disturbance has resulted in breeding failure. It is also essential that controls with zero disturbance from the activity are monitored. These conditions were met in the information from the Shropshire Wildlife Trust.

The necessary information with respect to the disturbance concerns the numbers and frequency of disturbers and the closeness of approach to the breeding birds whilst nesting. The numbers and frequency of orienteers in the proximity of nests were obtained from course
and entry details for the competition provided by the organisers, Harlequins Orienteering Club. The closeness of approach to nests was determined from the nest locations provided by the ornithologists and interpretation of the course data.

The objective of the study was to quantify as far as possible the levels of disturbance which resulted in four nests failing within the competition centre and the remaining nests in the competition terrain being unaffected.

Location of wheatear nests

The Shropshire Wildlife Trust ornithologists marked nest sites on a map based on the UK national Ordnance Survey (OS) 1:25000 cartography, colour photocopied and enlarged by a factor of 1.4, giving a working scale about 1:18000.

The positions of the nests were precisely known in the terrain because the orienteers visited them to ring the fledglings as part of their continuing monitoring of the population. The accuracy with which these nests were marked on the map may be estimated. The national OS map, because of the mine and quarry workings over the area, showed more detail than might normally be expected of moorland terrain. This allowed many of the nests to be precisely located on the map. The nest positions were marked by 5mm diameter discs, equivalent to 90m on the ground.

The centres of the discs were transferred to an orienteering map which had been surveyed at 1:7500 scale and printed at 1:10000. This map showed much more detail than the OS map, particularly in representing rocky terrain features. Since these features were those within which the wheatear nested, it was possible to either confirm the nest locations as transferred or make minor adjustments to locate the nests on or near mapped features. A small number of nests were marked in positions with no obvious feature on either map and the accuracy of these depended on the ornithologists’ judgement. With the exception of these last mentioned nests, to which attention is drawn in the detailed analyses, it is estimated that the actual position of each nest is within 25m of the point marked, after due deliberation, on the orienteering map.

The combined information on the orienteering courses together with the nest locations is given in Figure 1. There were 19 courses in all, ranging from those seeking to extract the maximum technical difficulty from the terrain to simple courses along the paths for very young children.

In addition to the nests shown on the map in Figure 1 there were a further 15 nests located in and around the working quarry adjacent to and south west of the competition area. These nests acted as experimental controls for the study.
Figure 1. A simplified reduced scale all-controls map of the orienteering event of 31 May 1999, showing the courses and the positions of wheatear nests (map by the author from information from Harlequins Orienteering Club).

The map shows two starts and one finish, the longer courses (659 competitors) starting at S1 and the shorter technical courses for older and younger competitors, and easier courses for novices, starting at S2 (514 competitors). The control circles on the courses are precisely positioned to an accuracy of 5m. The lines connecting the control points simply indicate the control sequence and do not necessarily represent the route to be followed on the ground. The map shows many of the courses apparently passing in close proximity to nest sites and causing transient disturbance. In addition, there is the prolonged disturbance associated with the competition centre. These two different conditions are considered separately, in that order.

Routes followed on the courses

In the Goodall and Gregory (1991) study at the Brandon Park event the researchers asked each orienteer, before leaving and while memory was fresh, to draw up on a second map the route he or she followed during the event. The Titterstone Clee research did not have that facility and an alternative method has had to be devised to determine competitor routes. The nature of the terrain at Titterstone Clee offers ground detail recognition and fine navigation but little route choice between well-balanced options. This means that, for the majority of experienced competitors, the best route for each leg from one control to the next, as identified by any one competitor, will closely match that of any other. It is possible from the map alone, because of its accuracy and consistency in representing the terrain, for any orienteer experienced in the checking of courses and competitor performance, to make a good estimation of the best route. The methodology is illustrated in Figure 2 which shows leg 1-2 on two of the longer courses.
Figure 2. An example of most likely route. (map by the author from the Titterstone Clee orienteering map at 1:10000, the yellow open area colour being omitted for clarity).

The competitors attempt to select the quickest route from Control 1 to Control 2. The straight line connecting the controls is not a viable choice because it passes over the extensive and difficult boulder field clearly marked on the map. The southern route option is shorter but involves climbing back up the hill, dropping steeply between the boulder fields and following a compass bearing towards the control feature, a small re-entrant. If the control is missed, the competitor has no readily identifiable catching feature. On the other hand, the northern route option is downhill all the way, with gentler gradients. This route skirts the boulder field leading to the second of the two marshes, which acts as precise starting point for a compass bearing to the control feature. If the control is missed, the competitor is caught by the readily identified long gully parallel to the bottom edge of the map segment. The northern option, although longer, is both quicker and less time penalising in case of navigation error. It may safely be assumed that an overwhelming majority of competitors, perhaps all, will have made this particular choice.

The same methodology applies to all route selection. Although some selections are not as clear cut as in the example above, the same principle of preference can be applied. In all cases of off-track movement the positional accuracy of most likely routes is about 25m, where paths are on route, the accuracy is better than 5m.

Parameters for disturbance

Without very detailed knowledge of specific behaviour of birds it is not possible to specify levels of disturbance. Instead, we can identify different levels of activity which are potentially disturbing and postulate that a general correlation between activity and disturbance exists.

In doing this there is an important difference between the Brandon Park and Titterstone Clee studies. The ornithologists at Brandon Park did not locate nests but made assumptions about where these might be within the territories the birds were holding. Therefore, the precise locating of the nests on Titterstone Clee results in less uncertainty in estimating potential disturbance.

The Brandon Park study used the definitions of activity levels at that event given in Table 1. (Goodall and Gregory 1991, 13).

<table>
<thead>
<tr>
<th>Activity Level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>More than 200 competitors passing within 25m.</td>
</tr>
<tr>
<td>High</td>
<td>100-200 competitors passing within 25m OR more than 200 competitors within 100m.</td>
</tr>
<tr>
<td>Medium</td>
<td>10-100 competitors passing within 25m OR 100-200 competitors within 100m.</td>
</tr>
<tr>
<td>Low</td>
<td>Fewer than 10 competitors passing within 25m OR up to 100 competitors within 100m.</td>
</tr>
</tbody>
</table>

Table 1. Activity levels at the Brandon Park bird study (Goodall and Gregory 1991).
The same protocol was used in this study, but with important modification and extension. The Titterstone Clee event had twice the number of competitors and the activity level table needs to reflect that. But first a distinction has to be made between the total number of competitors passing a point throughout the duration of the event and the maximum sustained rate, the latter being a better measure of disturbing activity. For the Brandon Park event the graph of percentage of competitors in the competition area with time (Figure 3) may be approximated to a short plateau at 50% lasting for one hour.

Figure 3. Proportion of competitors present in the competition terrain during an orienteering event at Brandon Park, Suffolk on 11 May 1991 (Goodall and Gregory 1991).

Table 1 can therefore be modified to show the maximum sustained rates of activity by halving the competitor numbers. These maximum sustained rates are given in Table 2.

Table 2. Maximum activity rates at the Brandon Park bird study 1991

<table>
<thead>
<tr>
<th>Maximum sustained activity rate</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra High</td>
<td>More than 200 competitors per hour passing within 25m.</td>
</tr>
<tr>
<td>Very High</td>
<td>100-200 competitors per hour passing within 25m OR more than 200 competitors per hour within 100m.</td>
</tr>
<tr>
<td>High</td>
<td>50-100 competitors per hour passing within 25m OR 50-100 competitors per hour within 100m.</td>
</tr>
<tr>
<td>Medium</td>
<td>5-50 competitors per hour passing within 25m OR up to 50 competitors per hour within 100m.</td>
</tr>
<tr>
<td>Low</td>
<td>Fewer than 5 competitors per hour passing within 25m OR up to 50 competitors per hour within 100m.</td>
</tr>
</tbody>
</table>

Figure 4. Comparison of competitor numbers in the terrain for Brandon Park (lower purple graph) and Titterstone Clee.

Table 3. Maximum sustained activity rates at Titterstone Clee

<table>
<thead>
<tr>
<th>Maximum sustained activity rate</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra High</td>
<td>More than 200 competitors per hour passing within 25m.</td>
</tr>
<tr>
<td>Very High</td>
<td>100-200 competitors per hour passing within 25m OR more than 200 competitors per hour within 100m.</td>
</tr>
<tr>
<td>High</td>
<td>50-100 competitors per hour passing within 25m OR 50-100 competitors per hour within 100m.</td>
</tr>
<tr>
<td>Medium</td>
<td>5-50 competitors per hour passing within 25m OR up to 50 competitors per hour within 100m.</td>
</tr>
<tr>
<td>Low</td>
<td>Fewer than 5 competitors per hour passing within 25m OR up to 50 competitors per hour within 100m.</td>
</tr>
</tbody>
</table>
Although the Titterstone Clee event had more competitors (~1200 compared with 480), they started over a longer period (3 hours instead of 2). The starting rates are therefore 400 competitors per hour compared with 240 competitors per hour at Brandon Park. Since the two events were of the same technical standard, planned to the same set of recommended winning times and giving the same overall average competing time of about one hour, their graphs of number of competitors in the terrain with time should have similar theoretical characteristics. In simplified form, both rise to a maximum after about one hour, plateau at that level until the last competitor starts, then decline. This is shown in Figure 4.

Since the maximum sustained activity rates were substantially higher at Titterstone Clee, it is necessary to extend the range above the top level used at Brandon Park.

The terminology is borrowed from the radio frequency spectrum. The upper value of 200 competitors per hour passing within 25m is not simply a symmetrical extension of the existing figures in the table but is based on the time the average competitor takes to cross a zone of 25m radius. The average straight line distance across such a zone is about 35m. The average speed of orienteers is in the region of 10 minutes per km (0.6 s.m⁻¹) and their time to cross the zone is about 20 seconds. If competitors were evenly spaced, a rate of 3 per minute would result in a constant presence within the zone. In reality, randomness prevails and competitors would overlap and, more importantly for birds feeding young, there would be gaps. Nevertheless, the point at which evenly spaced competitors would give constant presence within the zone is a useful marker. This is 3 per minute, or 180 per hour (rounded to 200 for the table).

Disturbing activity near nest sites in the competition terrain

For each of the nest sites approached within 100m by any of the courses the most likely routes followed by the competitors have been estimated in accordance with the procedures outlined above. These, together with overall competitor numbers and maximum sustained rate, have been illustrated on map segments, as given below. On each map the nest circle (blue) is 25m in radius and the map represents a 200m x 200m square. The control points are at the centre of each purple circle.
Figure 5. Nest 12
Accuracy of location poor
Total activity within 25m = Nil
Total activity within 25-100m = 517 (172 h⁻¹)
Maximum sustained activity rate - High

Figure 6. Nest 14
Accuracy of location moderate
Total activity within 25m = 258 (86 h⁻¹)
Total activity within 25-100m = 369 (123 h⁻¹)
Maximum sustained activity rate – High

Figure 7. Nest 26
Accuracy of location moderate
Total activity within 25m = Nil
Total activity within 25-100m = 227 (76 h⁻¹)
Maximum sustained activity rate - Medium

Figure 8. Nest 27
Accuracy of location moderate
Total activity within 25m = 64 (21 h⁻¹)
Total activity within 25-100m = 949 (316 h⁻¹)
Maximum sustained activity rate – Very High
Figure 9. Nest 28  
Accuracy of location good  
Total activity within 25m = 195 (65 h⁻¹)  
Total activity within 25-100m = Nil  
Maximum sustained activity rate - High

Figure 9. Nest 13  
Accuracy of location good  
Total activity within 25m = 609 (203 h⁻¹)  
Total activity within 25-100m = Nil  
Maximum sustained activity rate – Ultra High

Figure 10. Nest 31  
Accuracy of location good  
Total activity within 25m = Nil  
Total activity within 25-100m = 176 (59 h⁻¹)  
Maximum sustained activity rate - Medium

Figure 10. Nest 32  
Accuracy of location good  
Total activity within 25m = Nil  
Total activity within 25-100m = 144 (48 h⁻¹)  
Maximum sustained activity rate - Low
Figure 10. Nest 33
Accuracy of location good
Total activity within 25m = Nil
Total activity within 25-100m = 144 (48 h\(^{-1}\))
Maximum sustained activity rate - Low

Figure 11. Nest 34
Accuracy of location good
Total activity within 25m = Nil
Total activity within 25-100m = 659 (220 h\(^{-1}\))
Maximum sustained activity rate – Very High

Figure 12. Nest 35
Accuracy of location moderate
Total activity within 25m = 231 (77 h\(^{-1}\))
Total activity within 25-100m = 483 (161 h\(^{-1}\))
Maximum sustained activity rate - High

Figure 13. Nest 37
Accuracy of location good
Total activity within 25m = Nil
Total activity within 25-100m = 438 (146 h\(^{-1}\))
Maximum sustained activity rate - High
Figure 14. Nest 24
Accuracy of location good
Total activity within 25m = 329 (110 h⁻¹)
Total activity within 25-100m = 948 (316 h⁻¹)
Maximum sustained activity rate – Very High

Figure 14. Nest 38
Accuracy of location good
Total activity within 25m = 659 (220 h⁻¹)
Total activity within 25-100m = Nil
Maximum sustained activity rate – Ultra High

Figure 15. Wheatear nests in and around the competition centre
Disturbing activity near nest sites at the competition centre

The competition centre, comprising the car parking, administration and other facilities, as well as the assembly area for competitors before and after their courses, was situated in the derelict dolerite quarries near the top of the hill. This was an area of intense activity and here the four Wheatear nests were lost. Figure 15 shows the competition centre area and the road to the northern start (S1). The black circles indicate the nests which were abandoned.

The loss of the three nests 5, 36 and 45 is consistent with the level of activity in their immediate vicinity. The accuracy of location of the nests on the map is good and indicates the nests were adjacent to parked vehicles and tentage associated with the event. It was reported by Vickers (2000) that this was observed by ornithologists on the day. The level of activity cannot be quantified but would have been continuous over a period of 8 hours or more. The loss of nest 9 cannot be explained as readily. There was parking down the track adjacent to it but the level of disturbance from that and competitors walking along the track is not high compared with many other nest sites. However, the accuracy of its location on the map is poor and perhaps it was in a more vulnerable position than that shown.

Also of interest in this area are the three nest sites adjacent to the road along which 659 competitors walked to reach the northern start. These three nest sites 7, 46 and 29 are located on the map with good accuracy, all within 25m of the road. The same criteria can be used as for the calculations of maximum sustained activity rates in the competition terrain:

Nests 7, 29 and 46
Accuracy of location good
Total activity within 25m = 659 (220h⁻¹)
Total activity within 25-100m = Nil

Rating – Ultra High

It could be argued that the competitors walking to the start were potentially more disturbing than runners would be, because the walkers take longer to pass by and therefore the intervals between disturbances are shorter and less numerous. It could also be argued that birds near the road are more often subjected to disturbance and have become more tolerant of it.

Conclusion

Although the Wheatear *Oenanthe oenanthe* is not a protected bird in UK legislation, it is well regarded by ornithologists and the results of this disturbance study are of value. Four nest sites were lost in a general area of intense and prolonged disturbance. Of these, there was a clear cause and effect for three of the nests, with the orienteering tentage and vehicles variously described as being placed adjacent to nests. With the fourth nest there is insufficient information to confirm the same clear cause and effect.

A repeat of this interference with breeding Wheatears at orienteering events on Titterstone Clee is prevented by the working agreement between the ornithologists and the orienteering club.

Of the remaining 27 Wheatear nests within the competition area on the orienteering map, none appeared to have been affected by the event. Their potential disturbance from orienteering activity has been considered. In order to have consistency in bird disturbance reporting the methods of the Brandon Park breeding bird study (Goodall and Gregory 1991) have been used but with modification and extension. The modification is made to permit comparison and the extension arises because there were many nests within areas of orienteering activity at levels considerably higher than those specified in the Brandon Park report. These are shown in Table 4.
Table 4. Eight Wheatear nest sites exposed to potentially severe levels of disturbing orienteering activity.

<table>
<thead>
<tr>
<th>Maximum Sustained Activity Rate</th>
<th>Nest Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra High</td>
<td>7, 13, 29, 38, 46</td>
</tr>
<tr>
<td>Very High</td>
<td>24, 27, 34</td>
</tr>
</tbody>
</table>

The activity levels specified in the Brandon Park study have been converted from total competitor numbers activity levels to maximum sustained activity rates to permit comparison with this and any other similar study. An additional level, Ultra High, has been added to accommodate higher levels of disturbing activity. The threshold for this level has been set such that orienteers, or other runners, passing within 25m of nests would, if evenly spaced, present continuous presence within the 25m radius zone. In practice, randomness would produce significant gaps for the birds to exploit.

The positional accuracy of the siting of the nests and of the most likely routes taken by the orienteers in their vicinity has been considered and is generally of the same order as the 25m radius of the zone used for arriving at the highest levels of potentially disturbing activity given in Table 4. With eight nests calculated to be in the categories of ultra high and very high potential disturbance, errors in the calculation arising from positional uncertainty, which result in the potential disturbance being overstated, are likely to matched by others being understated.

The conclusion from this study is that the wheatear Oenanthe oenanthe, when feeding young, exhibits very considerable tolerance of disturbance. This conclusion is consistent with the reported siting of nests within a working quarry, one such nest positioned within 2m of the door of a workshop. It is also consistent with the ornithologist’s view that “the main activity of people running intermittently over the area was not the problem, since the feeding parent birds could seize the opportunity to dodge in when the coast was clear” (Vickers 2000). Although there appears to be no pressing need to take precautions to avoid the nests of wheatear raising young in the competition terrain of an orienteering event, particularly if the event is of modest size, if nest location information is available, it should be used to check, for example, that nests and control sites do not coincide.

The question arises as to whether the conclusions of this research apply to wheatear incubating eggs. Their behaviour and sensitivity under those conditions may not necessarily be the same as observed when they are feeding young. However, the ornithologist familiar with the wheatear on this site reports that the species exhibits at least the same degree of confiding behaviour when incubating (Fulton 2004). His experience of the flushing distance, the distance at which an approaching human causes the bird to leave the nest (Liddle 1997, 392), of the incubating wheatear is one metre or even less for a passing disturber, rather more for a stationary or near stationary disturber. More importantly, he estimates the return distance, the distance to which the human has to retreat before the bird returns to the nest, is about 25m. It is concluded, therefore, that the results of this study are applicable to the whole of the breeding cycle.

Although this is a single case study of the disturbance of one species of breeding bird at one site, it may be used for considering potential disturbance of breeding wheatear at other sites. It is also possible to draw tentative conclusions about other avian species which are known to have similar tolerance of disturbance to wheatear. One such species is the stonechat Saxicola torquata, which also nests on Titterstone Clee, in low gorse bushes. The ornithologist reports that, on this site, S. torquata appears to be at least as tolerant as O.
oenanthe, possibly even more so. He observes that S. torquata tend to sit tight on the nest and are not flushed until the bush is physically shaken.

Acknowledgements
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Robert Vickers – Harlequins Orienteering Club,
whose help with the acquisition of data and checking of the draft report is gratefully acknowledged.

References


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Spatial Orientation Ability in Boys and Girls Toddlers

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Abstract

The spatial orientation ability is very important for peoples' everyday life, as well as for their distinction to the sector of athletics, which depends on many endogenous and extraneous factors. The aim of present research was to study the effect of gender and athletic occupation in the orientation ability of children (boys and girls) of age 4 to 5 years old. On this survey participated 400 children who were evaluated with the “Witeba-Test of Spatial Orientation, (Temple, Williams and Bateman, 1979)”. Data were analyzed with 2-way ANOVA (gender x athletic occupation). The results revealed nonsignificant differences between boys and girls, between the children that did or did not participate in sports and no interaction either (p > 0.05). By inference, from the present study it appeared that the ability of orientation consists an inherent feature which at least during the early years of children's development, is not affected by the above factors.

Keywords: orientation ability, children, sports

Introduction

The orientation ability of each live organism in our planet determines his time duration of life, influences his survival and possesses important role in his reproduction (Thomas, 2006). The ability of planning and realization of activities in large areas is very important for the human functioning. The development of this ability can be accomplished by the very early years of age and the premature skilfulness implies that has been given particular care which helped the children to organize early in life (Hazen & Durett, 1982).

Kimura (1999) determines six spatial factors that have wide acceptance because they are distinctly determined from the experimental measurement: a) spatial orientation: it is the possibility of precise calculation of changes in the orientation of object. This ability is evaluated with two-dimensional (e.g. letters, numbers and simple forms) but also three-dimensional representations of objects (e.g. cubes, totals of cubes and photographs of real objects) rotated in general space, b) spatial memory: it is the ability of serial recall of objects. The tests involve series of realistic or geometrical objects that must be memorized, c) pursuit: it is the ability of throwing objects to a target, d) spatial vision: it is the possibility of recognition of changes of orientation in space and it's referring to the estimation of place of somebody concerning a static object, d) simplification: it is the ability of finding of object which belongs in a complex total, e) spatial perception: it is the ability of determination the horizontal and vertical directions in the space.

There is extended literature about sex differences concerning spatial ability, indicating that males tend to outperform females on spatial tests that require manipulations of geometric figures and forms (Hampson & Kimura, 1992, Linn & Petersen, 1985, Voyer, Voyer & Bryden, 1995). However, the tests that were used had a restricted laboratory nature. More specifically, spatial ability in humans typically is assessed using paper and pencil tests that require subjects to perform imaginary manipulations of geometric figures or objects, or otherwise perform any of a variety of visual transformations of stimuli presented on the printed page (Moffat, Hampson & Hatzipantelis, 1998). Additionally, even if the differences of two sexes, have been proved with the evident superiority of men (Harris, 1978, Maccoby and Jacklin, 1974), the age in which these differences appear for the first time, has not been clarified yet. Certain researchers support that reliable differences are presented only afterwards the puberty (Maccoby et al., 1974), while other disagree supporting that this differences in certain versions of spatial ability,
are visible also in children (Newcombe, 1982). These contradictions might exist because of the fact that are measured different characteristics each time and this because, the evaluation of certain abilities in young children is difficult. The determination of age at which are presented the first differences is important as it can provide information on the factors which contribute in them. The comprehension of factors that influence the appearance and the size of male advantage in spatial orientation is not only an interesting scientific question, but is also relative with the improvement of academic output of children and the further growth of current technological society (Levine, Vasilyeva, Lourenco, Newcombe and Huttenlocher, 2005).

The development of spatial ability might be influenced by other factors also, such as athletic occupation. However, Haydel (2000) in her research study, failed to confirm the hypothesized effect of athleticism on the spatial ability test scores of the female athletes 18-24 years old. Although there was not enough evidence to support the use of athletics as a tool for spatial ability development in young girls, insight was presented that suggests a specific type of athletic activity might be the most beneficial to spatial development.

The literature presented in the above paragraphs all provide a strong basis for understanding that spatial ability depends on several independent factors such as gender, nature of tests and athletic experience. There is lack of research that examines the beginning of the appearance of differences in spatial ability so that suitable educational programs may exist in school. The purpose of the current study was to investigate the effect of gender and athletic occupation of toddlers 4-5 years old in their spatial orientation ability.

**Methods**

**Participants**

Four hundred children (N=400) in the age of 4-5 years old participated in the study, 204 boys and 196 girls, from all the kindergartens of island Kos in Greece. The parents of all participants signed a consent form.

**Procedure**

For the evaluation of spatial ability the Witeba-Test of Spatial Orientation (Temple, Williams & Bateman, 1979) was used. This method included walking in straight line 6m without optical contact and measurement of divergence from the straight line in left, right and straight line direction. If the final reached point was in the left or right direction, the measurement included the calculation of the vertical distance from the straight line of 6m. If participant did not stop immediately afterwards the voice signal of examiner and exceeded the 6m, then it followed measurement of straight line of divergence also (Figure 1). The measurement in all the divergences became in cm. The exclusion of optical contact was realized with the use of dark colored scarf, which was tied up carefully round the participant's head covering the eyes. Five trials were realized and it was measured the mean score for each participant.

![Figure 1. Orientation test with walking in straight line 6m.](image-url)

A child was considered as sports occupied, if participated for more than from six months in organized program of training of certain sport, with frequency more than two times per week (Table 1).
Results

The results revealed that for the right divergence, there was not main effect concerning the gender ($F_{1,399}=1.046, p>0.05$), neither concerning the athletic occupation ($F_{1,399}=1.038, p>0.05$). There was not interaction either between gender and athletic occupation ($F_{1,399}=0.163, p>0.05$), (see Table 2).

<table>
<thead>
<tr>
<th>Sport</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballet</td>
<td>24</td>
<td>6%</td>
</tr>
<tr>
<td>Tennis</td>
<td>11</td>
<td>2.75%</td>
</tr>
<tr>
<td>Karate</td>
<td>9</td>
<td>2.25%</td>
</tr>
<tr>
<td>Dance</td>
<td>8</td>
<td>2%</td>
</tr>
<tr>
<td>Soccer</td>
<td>5</td>
<td>1.25%</td>
</tr>
<tr>
<td>Basketball</td>
<td>3</td>
<td>0.75%</td>
</tr>
<tr>
<td>Track &amp; Field</td>
<td>1</td>
<td>0.25%</td>
</tr>
</tbody>
</table>

Table 1. Sport, number and percentage of children occupied with athletics

For the left divergence, there was not main effect concerning the gender ($F_{1,399}=1.428, p>0.05$), neither concerning the athletic occupation ($F_{1,399}=0.294, p>0.05$). There was not interaction either between gender and athletic occupation ($F_{1,399}=0.092, p>0.05$), (see Table 3).

Statistical analysis

For evaluating the effect of gender and athletic occupation in spatial ability in children, it was applied analysis of variance with two factors (two-way Anova, 2x2) with significance level $p<0.05$.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Athletic occupation</th>
<th>M</th>
<th>S.D.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
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<td>48.80</td>
<td>184</td>
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<tr>
<td></td>
<td>Yes</td>
<td>49.20</td>
<td>53.94</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>58.93</td>
<td>49.29</td>
<td>204</td>
</tr>
<tr>
<td>Girls</td>
<td>No</td>
<td>64.68</td>
<td>54.36</td>
<td>155</td>
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<td></td>
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<td>60.01</td>
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<td></td>
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<td>53.79</td>
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<tr>
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<td>62.13</td>
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<td></td>
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<td></td>
<td>Total</td>
<td>61.27</td>
<td>51.53</td>
<td>400</td>
</tr>
</tbody>
</table>

Table 2. Means & Standard Deviations for boys and girls for the right divergence
For the distance from the straight line of 6m, there was not main effect concerning the gender ($F_{1,399}=1.321$, $p>0.05$), neither concerning the athletic occupation ($F_{1,399}=4.189$, $p>0.05$). There was not interaction either between gender and athletic occupation ($F_{1,399}=0.657$, $p>0.05$), (see Table 4).

Finally, for both left and right divergence, there was not main effect concerning the gender ($F_{1,399}=3.773$, $p>0.05$), neither concerning the athletic occupation ($F_{1,399}=2.968$, $p>0.05$). There was not interaction either between gender and athletic occupation ($F_{1,399}=0.739$, $p>0.05$), (see Table 5).

### Table 3. Means & Standard Deviations for boys and girls for the left divergence.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Athletic occupation</th>
<th>M</th>
<th>S.D.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
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<td>47.66</td>
<td>184</td>
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<td></td>
<td>Yes</td>
<td>65.41</td>
<td>56.41</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
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<td>48.43</td>
<td>204</td>
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<tr>
<td>Girls</td>
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<td>70.25</td>
<td>50.90</td>
<td>155</td>
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<tr>
<td></td>
<td>Yes</td>
<td>76.52</td>
<td>57.81</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>71.56</td>
<td>52.33</td>
<td>196</td>
</tr>
<tr>
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<td>339</td>
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<td></td>
<td>Yes</td>
<td>72.88</td>
<td>57.13</td>
<td>61</td>
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<tr>
<td></td>
<td>Total</td>
<td>67.61</td>
<td>50.46</td>
<td>400</td>
</tr>
</tbody>
</table>

### Table 4. Means & Standard Deviations for boys and girls for the distance from the straight line of 6m.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Athletic occupation</th>
<th>M</th>
<th>S.D.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>No</td>
<td>1.53</td>
<td>5.55</td>
<td>184</td>
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<tr>
<td></td>
<td>Yes</td>
<td>3.87</td>
<td>7.99</td>
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<tr>
<td></td>
<td>Total</td>
<td>1.76</td>
<td>5.85</td>
<td>204</td>
</tr>
<tr>
<td>Girls</td>
<td>No</td>
<td>1.25</td>
<td>4.83</td>
<td>155</td>
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<tr>
<td></td>
<td>Yes</td>
<td>2.26</td>
<td>6.85</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Total</td>
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<td>5.31</td>
<td>196</td>
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<tr>
<td>Total</td>
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<td>1.40</td>
<td>5.23</td>
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<td>2.79</td>
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<tr>
<td></td>
<td>Total</td>
<td>1.61</td>
<td>5.59</td>
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</tr>
</tbody>
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Discussion

Although the majority of the previous researches revealed an undoubtable superiority of men in spatial orientation ability, the results of the present study do not support something similar for boys toddlers. Goluccia & Louse (2004), studying the orientation ability in different environments, they led to the male supremacy, reporting however and regularly percentages of cases where were not found differences between the two sexes. In contrast, Alexander, Packard & Peterson (2002), they led to the supremacy of women in memory test, that constitutes part of spatial ability. The differences of two sexes that are observed in certain categories of spatial ability and awareness more generally appear to be owed in interrelated biological variables, more specifically in the differences in the genital hormones but also in the regional maturation of brain (Levy & Heller, 1992). According to Levy (1970), it will not be rejected the opinion that the deficient spatial perception of women is a genetically determined disability that is related with the operation of cerebral hemispheres. The women tend to use the left hemisphere that is accountable for the oral reason and it is poorer in the questions of space.

The social elements play also important role. The pastime of boys in the small age with LEGO, puzzles and video games, can promote their spatial ability (Levine et al., 2005). However, these differences tend to be eliminated nowadays, as both boys and girls deal equally with electronic games. The results of the present research come in contrast to them of researches that support the differences of sex in the spatial ability in early childhood (Cronin, 1967; Levine et al., 1998; Wiedenbauer & Jansen-Osmann, 2006; Gibbs & Wilson, 1999; Uttal, Gregg & Chamberlain, 1999). This can happen because the orientation ability is constituted by a lot of components that are not examined in combination with other factors. Fundamental role played also the nature of test evaluation that was used in the present research, that contrary to what is reported in the bibliography, it is a particularly field test, fact that potentially influenced the results.

Also, the athletic occupation does not influence the orientation ability, perhaps because it needs enough time to elapse in order to appear any differences to performance. The age, in which these differences are presented, has not been ascertained from up to now researches. In order to detect in which age these differences begin to emerge, should be applied researches in older ages, that is to say in children between 6-18 years old. Also, the type and the quantity of pastime with out of school athletic activities should be investigated. Finally, it is proposed next studies to investigate also the ways with which the teachers develop

<table>
<thead>
<tr>
<th>Gender</th>
<th>Athletic occupation</th>
<th>M</th>
<th>S.D.</th>
<th>N</th>
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</thead>
<tbody>
<tr>
<td>Boys</td>
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<td>79,34</td>
<td>36,50</td>
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<td></td>
<td>Total</td>
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<td>204</td>
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<td>Girls</td>
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<td></td>
<td>Total</td>
<td>81,18</td>
<td>40,27</td>
<td>400</td>
</tr>
</tbody>
</table>

Table 5. Means & Standard Deviations for boys and girls for the left & right divergence
the orientation ability of children through playful activities.

References


Voyer, D., Voyer, S., and Bryden, M.P.  
Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables.  


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Fatigue and Perception de l’effort pendant une course d’orientation

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From the 1 Laboratoire Activité Motrice et Conception Ergonomique (AMCO) and the 2 Laboratoire Electronique Singal Image (LESI), University of Orléans, France.

Abstract
We tried to analyse the effort during an orienteering race by working on the objective and objective perception of the effort made by the runner before during and after a race. This experiment was supervised by 12 highly skilled orienteers. The runners were given an electrocardiogram during an orienteering race and during a stand test before and after the race. The electrocardiogram data were analysed thanks too techniques linear (Pburg, F.F.T.), no-linear (Poincarré), and time-frequency (Morlet wavelet). Interviews focused on the progress of the race were achieved to get information in order to correlate with the electrocardiogram recordings. Statistics on stand tests were achieved as well as the study of correlations between the different variables of electrocardiogram and the observable were looked for too. We tried to throw light on the spectrogram from the observables thanks to the interviews and Morlet wavelet too. We notice many changes after the effort in comparison to the variables of rest before the effort. We can also observe a psychological influence on the energy High Frequency and a physiological difference on the energy Low Frequency. The Low Frequency would be a reliable marker of the cognitive effort put in the task during the orienteering race. These results could help us manage the effort in a finer way working with the athletes in order to put in place a system of help which will improve the diagnosis of the orienteer.

Keywords: orienteering, perceived exertion, HRV, interviews, psychology, physiology.

Introduction
L’objet de cette étude a été d’apprêhender les contraintes biologiques et psychologiques en course d’orientation, en travaillant sur l’objectivation de l’effort du sujet dans sa dimension physiologique et sa perception subjective, avant, pendant et après une course.

Cadrage
Une approche transversale de l’étude de la fatigue a été privilégiée. Ainsi, nous avons intégré dans notre étude des méthodes provenant de l’anthropologie cognitive et de la physiologie afin d’analyser l’activité de course d’orientation.

Le sportif effectue un parcours de course d’orientation seul et aidé d’outils caractéristiques à sa pratique (carte, boussole) dont il conserve l’entièr maîtrise. La performance du coureur est conditionnée par des contraintes multiples du fait de son évolution dans un milieu ouvert et complexe. C’est pourquoi les données physiologiques ne permettent pas à elles seules d’expliquer la dynamique de la réussite sportive. Il convient également de prendre en considération les conditions dans lesquelles sont réalisées la performance ainsi que les facteurs subjectifs (les ressentis, motivations,...) dans le cadre d’une approche de la cognition du coureur. Il importe alors de replacer le coureur en contexte pour étudier ses actions son environnement complexe de pratique.

Pour saisir au mieux cet environnement dynamique, comme le souligne Plaza (1989), l’étude de l’individu, en situation implique une interdisciplinarité au plan théorique et une utilisation de divers outils au plan pratique car chaque spécialiste n’a du problème qu’une vue fragmentaire en relation avec l’objet de sa propre étude. Nous avons donc essayé d’éclairer notre problématique conjointement à partir de données issues de l’analyse de la variabilité de la fréquence cardiaque (HRV) et de données « subjectives » issues des entretiens.

Des auteurs tels que Karppinen (1994) ou Peck (1990) ont montré, en s’intéressant à diverses variables physiologiques, que nous ne
pouvions établir aucun rapport, ni aucune évolution linéaire en comparant les efforts fournis lors d’une course en tout-terrain par rapport aux études de laboratoire. La course d’orientation est une activité atypique qu’il convient d’étudier en milieu naturel, la réponse physiologique en course d’orientation étant singulière. Nos expérimentations auront donc pour base des situations réelles sur le terrain de pratique habituelle. Cependant, les situations de pratiques n’étant pas réductibles à des situations reconstruites en laboratoire, situations plus « artificielles » que les situations de pratiques originelles, il est difficile d’y appliquer un contrôle expérimental rigoureux. La profusion des variables impliquées dans les situations de pratiques, ainsi que les multiples interactions entre ces variables, rendent délicate la validité de l’explication et hasardeux son degré de généralisation. (Grison, B. & Riff, J., 2002)

**Anthropologie cognitive – action située**


**Physiologie – Variabilité de la fréquence cardiaque**

Le système autonome est constitué par deux entités : i) le système nerveux parasympathique, ii) le système sympathique ou orthosympathique. La régulation de la fréquence cardiaque est la conséquence d’un « couplage » subtil de ces deux systèmes : la balance sympatho-vagale. Le système nerveux parasympathique est surtout prédominant dans les situations dites de repos (en opposition aux activités physiques) : il est notamment associé au repos et à la digestion. Son rôle principal consiste à minimiser la consommation d’énergie tout en permettant l’accomplissement des fonctions vitales. Par contre, le système nerveux sympathique prédomine sous des conditions de stress, comme dans des situations d’urgence (e.g. fuite ou lutte) ou encore lors d’activités physiques. Son influence se caractérise par une augmentation des fréquences cardiaques et respiratoires.

Cette balance peut-être observée à travers l’activité cardiaque. En effet, lorsqu’une analyse de la variabilité de la fréquence cardiaque est réalisée, différentes gammes de fréquences ont été définies en relation avec l’activité de ces deux systèmes. Des quantifications peuvent être réalisées dans le domaine temporel et fréquentiel. (Task Force of European Society of cardiology, 1996) Différentes méthodes permettent de passer d’un signal temporel à un signal fréquentiel. On peut distinguer deux approches : celles paramétriques et celles non-paramétriques. Les approches paramétriques permettent de simplifier le signal étudié afin de mettre en évidence des fréquences spectrale de fréquences. Leur inconvénient est dû à la nécessité du choix du paramètre qui peut être très délicat dans certains cas. De plus, lorsqu’il est nécessaire de suivre l’évolution d’un signal, il est préférable
d’utiliser un signal qui supporte le fait que ce dernier varie en fonction du temps (non-stationnariat).

Dans le domaine fréquentiel, deux bandes de fréquences pertinentes sont mises en évidence (Akselrod 1981) :

- une bande haute fréquence (HF) centrée sur le rythme respiratoire, et contrôlée par le système nerveux parasymptathique, ≥ 0,15 Hz ;
- une bande basse fréquence (LF), contrôlée par les systèmes nerveux symphysique et parasymptathique, probablement témoin de la sensibilité du baroréflexe, 0,04 ≤ LF < 0,15 Hz ; La bande LF étant le reflet du contrôle des deux systèmes : symphysique et parasymptathique, pour évaluer l’importance de l’action du système symphysique, il est intéressant d’étudier le ratio LF/HF ;


Nous analyserons les ECG des coureurs en tentant de corréler ces analyses aux observations réalisées et aux données extraites des entretiens non-directifs centrés sur l’action singulière étudiée. Ces méthodes seront employées dans le but de prendre en considération toute la spécificité de l’objectif initial : apprécier l’effort en cours d’orientation, en travaillant sur la perception objective et subjective de l’effort du sujet, avant, pendant et après une course d’orientation.

Nous espérons pouvoir, grâce à ces dispositions, trouver un marqueur physiologique sensible à l’effort investi dans les tâches mises en jeu lors d’une course d’orientation.

Méthode

Ce travail a été mené en collaboration avec des athlètes de haut-niveau, issus du Pôle France de St-Etienne. Le groupe de sujet était composé de 12 orienteurs, tous en équipe de France.

Procédures générales

Le recueil de données a été réalisé en deux volets distincts. A l’origine, tous les sujets auraient dû être présents le même jour pour que les différents recueils de données soient récoltés dans les mêmes conditions.

Protocole

Le coureur devait réaliser un parcours d’orientation, soit lors d’une compétition (n=5), soit lors d’un entraînement (n=7). Les coureurs étaient équipés d’un holter qui enregistrait leur ECG et réalisaient un test orthostatique (Hedelin et al., 2001), avant et après la course. Ce test consiste en la mesure de l’ECG pendant 5 min de repos en position allongée suivie de 6 min en position debout. La fréquence respiratoire était libre. De plus, L’ECG était enregistré en continu pendant la course. A la suite de la course un entretien non-directif, centré sur sa course et ses perceptions était réalisé pour obtenir des informations à corréler avec les enregistrements ECG.

Recueil de données

L’enregistrement de l’ECG a été réalisé sur 2 voies avec une fréquence d’échantillonnage à 500 Hz pendant les tests orthostatiques avant et après la course, ainsi que pendant la course.

Figure 25 : Déroulement du recueil de données.
Pour recalmer nos données issues de l’ECG et de l’analyse du terrain, nous avons utilisé deux niveaux distincts de « sections » :
- sections correspondants au découpage du circuit, poste par poste ;
- sections plus restreintes correspondantes au découpage du circuit, observable par observable (à chaque modification d’altitude, de pente,...) ;
Le temps du circuit n’étant connu que poste par poste, pour resituer les bornes temporelles de ce type de sections, nous avons eu recours à un calcul de moyennées de vitesse sur l’intervalle. (figure 2)

Figure 2 : exemple de découpe en sections et moyennage de la vitesse.

Les entretiens non directifs effectués pour l’étude se rapportent à une action effective : le déroulement de sa course. Le coureur essaie de revivre sa course et d’en raconter le déroulement. Le sujet débute son discours par les premiers événements auxquels il attribue de l’importance par rapport au déroulement de sa course. La seule question formulée était celle du démarrage. Toutes nos autres interventions n’étaient que des recadrages ou des éclaircissements du discours tenu par le sujet. J’essayais de mettre en confiance l’athlète et je lui conseillais d’avoir un déroulement chronologique par rapport à son action. L’évaluation du ressenti du coureur de sa vitesse de déplacement était aidé par un outil : il pouvait m’indiquer, à l’aide de trois couleurs (vert, orange, rouge) sa vitesse de déplacement, ce qui lui permettait généralement de se « lancer » (figure 3)

Figure 26 : codage de la vitesse ressentie par le coureur.

Traitement
Le traitement nous a permis d’obtenir trois types de données :
- issues de l’activité de déplacement (temps intermédiaires, dénivelé, nature du terrain,...) (= les traces de l’activité) ;
- issues de l’enregistrement (ECG);
- issues des verbalisations recueillies a posteriori.

La variabilité de la fréquence cardiaque a été évaluée à partir des enregistrements ECG afin d’observer les modifications de la réponse du système autonome à l’effort.
Les données ECG ont été traitées à l’aide du logiciel Matlab® 6.5.
Le calcul de l’écart-type des intervalles RR (SDNN) a été réalisé.
Les différentes bandes de fréquence de la HRV ont été calculés au moyen d’une analyse paramétrique (Pburg [ordre du P fixé à 9]) et d’une analyse temps-fréquence par ondelette continue de Morlet. L’énergie des différentes bandes de fréquences (LF, HF) obtenue au moyen des techniques ci-dessus étaient normalisées à l’énergie totale des deux bandes et permettait de définir LFnu et HFnu respectivement suivant la formule (Cottin, 2003) :
LFnu = LF/(LF+HF)*100 ; HFnu = HF/(LF+HF)*100

Procédures statistiques
Des statistiques sur les test orthostatique position allongée v.s. position debout, ainsi que des comparaisons avant v.s. après ont été réalisées au moyen d’un test sur les rangs de Wilcoxon (logiciel SigmaStats v.3 Systat®). Les seuils de significativités étaient fixés à $p \leq 0,05$.

Corrélation du spectrogramme aux observables

Résultats
Résultats des tests orthostatiques
Pendant les stand-tests, c’est la comparaison des valeurs obtenues dans la station debout, avant v.s. après l’effort, qui met en évidence le plus de modifications.

Résultats issus de la modification de posture (allongé v.s. debout) avant l’effort
Concernant le ratio LF/HF, le travail sur les pôles de Pburg montre une augmentation significative entre la position allongée et debout avant l’effort ($p=0,01$) (Task force, 1996)

A propos des valeurs normalisées, les deux méthodes nous donnent les mêmes résultats significatifs : ils mettent en évidence une augmentation de LFnu avant l’effort pendant la modification de la position (allongé v.s. debout) et en même temps une diminution de HFnu avant l’effort.

Résultats issus de la modification de posture (allongé v.s. debout) aprés l’effort
On peut observer une augmentation de LFnu après l’effort et en même temps une diminution de HFnu après l’effort pendant la modification de la position (allongé v.s. debout).

Résultats issus de la comparaison en station allongée avant v.s. après l’effort
A propos de SDNN, une augmentation significative est observée entre les positions allongées avant v.s. après ($p=0,008$).
Résultats issus de la comparaison en station debout avant v.s. après l’effort

La bande HF présente une augmentation significative que se soit avec la méthode paramétrique \((p=0,005)\) ou la méthode temps – fréquence \((p=0,005)\).

Le ratio LF/HF indique une différence (augmentation) entre la stature debout, avant v.s. après la course \((p=0,033)\).

A propos de SDNN, une augmentation significative est observée en position debout avant v.s. après \((p=0,03)\).

Résultats en situation de course

Voici un exemple mettant en évidence les relations entre un spectrogramme issu de l’analyse temps-fréquence et la verbalisation correspondante (Figure 5). Les facteurs psychologiques comme les erreurs, la lecture de carte dans les zones complexes,... augmentent la puissance de la bande HF, alors que les facteurs physiologiques tels que la vitesse de course, l’utilisation des chemins,... augmentent la puissance de la bande LF. Cette relation est également remarquée pour les cinq autres sujets.

Figure 5 : exemple d’une corrélation entre spectrogramme et observables pour un sujet.

Discussions

Il est à noter l’écart-type très fort pour toutes les données : le type d’effort (dénivelée, nature du terrain, nature du circuit), influence énormément la réponse individuelle (Karppinen, 1994, Peck, 1990). Nos données étant parfois hétérogènes, (phénomène amplifié par le fait que tous les coureurs exploitables ont couru sur des circuits différents), à titre d’indication, nous avons fixé un seuil de significativité supplémentaire à \(p \leq 0,055\) pour rendre compte d’une tendance.
Travail sur les stand-tests

L’augmentation de l’écart-type des intervalles R-R (SDNN) révèle que le sujet fatigué à une plus grande variation de la durée de ces intervalles, comme l’observe Jouanin (2004) après une fatigue prolongée suite à un effort de 7 jours. Il faut tout de même indiquer que l’évolution entre les 2 stations (allongé et debout) n’a pas la même influence avant et après l’effort : alors qu’avant l’effort, il n’y a quasiment aucune variation de SDNN (p=0,966), après l’effort, cette modification de posture diminue SDNN ainsi que le p (p=0,547). (figure 4)

Figure 4 : variabilité à court-terme.

Ceci nous permet d’émettre l’hypothèse que l’écart-type des intervalles R-R a tendance à diminuer rapidement après l’effort pendant le repos (pendant le test orthostatique) et que si les tests orthostatiques, au lieu d’avoir lieu dans les minutes suivant l’arrêt de l’effort, avaient eu lieu dans l’heure suivante, il est fort probable qu’aucune, ou très peu, de variations auraient été observées.

Dans notre étude, le ratio LF/HF augmente entre les positions allongé v.s. debout au repos et montre donc que la bande LF a plus d’importance par rapport à la bande HF au repos (Task force, 1996). Le partage est encore plus inégal après l’effort. Comme la bande HF augmente dans ces conditions, l’augmentation est due à un accroissement plus important de LF, ce qui nous permet de conclure que le système sympathique, a plus d’importance après l’effort, dans notre situation. L’analyse des valeurs normalisées de LF (LFnu) et HF (HFnu) vient corroborer l’évolution du ratio LF/HF.

L’augmentation de ce ratio montre la prépondérance du système sympathique après l’effort. Ceci s’oppose à d’autres études qui ont observé une augmentation de l’activation du système parasympathique après l’effort (Jouanin et al., 2004). Cette différence peut peut-être s’expliquer par le moment de réalisation des tests orthostatiques après l’effort. En effet, dans le cas de la récupération, la diminution de la fréquence cardiaque est d’abord due à l’activité du système sympathique puis du parasympathique (Pierpont et al., 2000). Ici, les sujets ont réalisé leur test orthostatique alors que leur fréquence cardiaque était encore assez élevée, la balance entre les deux systèmes serait peut-être différente si les tests orthostatiques avaient eu lieu un peu plus tard. L’évolution de la valeur SDNN vient appuyer cette hypothèse. (figure 4)

Nos données recoupent donc les données trouvées en laboratoire et sur le terrain par d’autres études. Ceci nous permet de penser que les méthodes utilisées dans cette étude, ainsi que les données obtenues, sont fiables et valides.

Travail sur les résultats intra-individuels

Il est intéressant de remarquer que l’analyse qualitative des spectrogrammes nous a permis de formuler l’hypothèse que la bande LF serait plutôt liée aux régulations de l’effort physique (e.g. la vitesse), et la bande HF aurait un lien avec la contrainte cognitive et des situations contraignantes ponctuelles (e.g. erreurs). Toutefois, l’influence de ces facteurs psychologiques pourrait être indirecte : la lecture de carte demande une stabilisation de la carte, et par extension, des bras, ce qui induit un ralentissement de la vitesse de course. C’est ce ralentissement, qui pourrait être à l’origine de l’augmentation de la bande HF. Néanmoins, des facteurs comme les erreurs, qui n’influençent pas la vitesse de course, entraînent les mêmes modifications sur la bande HF, ce qui nous laisse penser que cette bande réagit directement aux facteurs psychologiques. Même si cette hypothèse n’est pas invalidée par nos données, cela ne signifie pas pour le moment, qu’elle soit généralisable à un autre type d’effort ni même à une autre population. Nous pouvons juste remarquer les fortes récurrences qui
viennent approuver cette hypothèse sous nos conditions.

La suite de l’étude va donc nous amener à essayer de quantifier ces variations en étudiant plus de sujets et en utilisant des méthodes statistiques multifactorielles.

Si notre hypothèse est valide, cela signifie que la bande HF pourrait être un marqueur de l’effort cognitif même lorsqu’il y a concomitance avec un effort physique soutenu. (Letourmy - Lecarpentier et Larue, 2000) Cependant, leurs expériences se déroulaient en laboratoire, sous variables contrôlées, avec un effort physique limité et bien délimité.

Si nos travaux futurs venaient soutenir cette hypothèse, il serait alors possible de quantifier finement l’énergie investie au cours de l’activité : nous pourrions ainsi dépasser les échelles classiques de perception de l’effort, en proposant une granularité plus fine et plus fiable de l’effort investi dans la tâche. Cela nous permettrait de travailler très finement sur la gestion de l’effort en collaboration avec les athlètes en vue de co-construire un système d’aide. Cela pourrait nous aider à chiffrer qualitativement l’énergie investie dans les tâches cognitives.

Ce type d’analyse agirait sur les coureurs comme un accélérateur d’expérience, pour leur permettre une prise de conscience fine de leurs capacités physiologiques et psychologiques ; mais surtout de l’effort investi dans la tâche, qu’il soit mental ou physique. Au même titre que les dépenses physiques, nous pourrions fournir à l’athlète des outils pour évaluer sa dépense mentale. L’objectif sera alors de doter le coureur de marqueurs utiles à la gestion de son effort, aussi bien mental que physique. En conséquence, cette méthodologie devra s’intégrer, au même titre que la préparation physique, dans la planification quotidienne de l’entraînement de ces athlètes.

Conclusion

Pour la suite de cette étude, il paraît tout de même indispensable de modifier quelques points du protocole actuel pour nous permettre de prendre en considération les remarques formulées ci-dessus :

- Il faut faire courir tous les sujets sur le même circuit pour réduire au maximum le nombre de variables en jeu ; Tous les sujets seront confrontés aux mêmes caractéristiques du terrain, de la carte...
- Tous les coureurs doivent avoir le même circuit, par exemple en alternant un circuit imposé (un suivi d’itinéraire : tous les sujets ont le même parcours réel, avec la même dénivelée, la même végétation, les mêmes problèmes de lecture de carte,...) et un circuit classique (comme cette année, où le coureur est libre de son itinéraire) ;
- la limite la plus indéniable, qui n’a pas pu être contournée faute de matériel adéquat cette année, est le grain d’analyse trop gros ; La découpe des sections et le moyennage de la vitesse pour recaler les différents observables induisent un décalage trop significatif dès lors que les postes à postes sont éloignés, et/ou avec une dénivelée discontinue ; Pour passer outre ce problème, l’équipement de G.P.S. de chaque coureur devient obligatoire ; Cela permettrait de détailler les sections avec une finesse de grain qui autorise le recalage de n’importe quelle observable à l’ECG sans dérive (Figure 2, page 4). Dès que nos mesures auront une granularité temporelle plus fine, des analyses statistiques multifactorielles pourront être réalisées.

Ces améliorations devraient nous permettre d’appréhender encore mieux, en temps réel, l’activité des orienteurs en course.

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The Use of New Technologies in Making Orienteering Maps

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Abstract

Orienteering maps are special types of maps that are mostly made by non professionals. The technology of making these maps (ground survey and drawing) has considerably changed during the last twenty years.

Base maps can be made by digital photogrammetry or airborne laser scanning technology, but the methods of creating state topographic maps (which are used as the base maps of many orienteering maps) have also changed in the past few years. The accuracy of these maps has also increased to help the users.

In the ground survey (fieldworking), we can use GPS devices (sometimes with real-time differential corrections) for measuring points and lines. GPS devices have been available for more than twenty years, but they have been used in ground survey as regular techniques only in the last few years. For faster distance measurements we can use laser distance finders.

Most orienteering maps are drawn using computer software. In some countries new to orienteering, this the only ways maps have been drawn.

Orienteering maps are good indicators of how the new cartographic techniques are easily applicable for non professionals and how widely they are used as everyday techniques.

This paper summarises the milestones of the development of these techniques to understand how we can make these methods and devices more user-friendly and simpler.

Introduction

Orienteering maps are one of the very few types of maps that have the same specifications all over the world. Another example is the aeronautical chart, which is completely standardised due to the importance of the international air traffic. Theoretically, there should be no national deviations in orienteering maps. Although there can be some in practice, they are not relevant and/or only used in local events. Every country inspires their mapmakers to use the latest version international orienteering map specifications (ISSOM2000) so that their competitors are not disadvantaged in International events.

Orienteering maps are special, because to make them suitable for orienteering the map makers have to be familiar not only with the map specifications, but also with the rules and traditions of their sport. To be a cartographer only does not guarantee that we can make excellent or even suitable orienteering maps – it is more important to be an experienced orienteer.

Generally, the mapmakers of orienteering maps are not professional cartographers. To help their work or even to make their work possible, they need good base maps, which can be normal topographic maps or special photogrammetric plots.

Short overview of orienteering maps

The sport started as a military navigation test at the second half of the 19th century. The first civil (non military) event was organised at the end of the 19th century (Norway: 31st October 1897, Sweden: 1900, Denmark: 1906).
Scandinavia is still the most developed region of orienteering. The main reason is probably the very complicated glacial terrain compared to Continental or Mediterranean type areas, but mostly the long term tradition of using topographic maps. In every country where orienteering was practiced before the foundation of the International Orienteering Federation (IOF, 1961), local topographic maps were used for the events and training.

The early period of orienteering maps was the age of homemade maps. In most countries (excluding Scandinavia), there were no suitable maps available for public use. According to the running speed and the course distance the scale of maps was 1:20 000-1:40 000 (1:50 000-1:100 000 in the early years). In some countries, the topographic maps were classified (Eastern Europe), in other areas the largest available scale of topographic maps was only 1:50 000 (Germany, Spain). Using tourist maps was a logical alternative, but in Eastern Europe the accuracy of publicly available tourist maps was not suitable for these events. Therefore, these countries tried to find more accurate tourist maps published before the communist era.

There was also a problem of copying. The only simple method of making some dozens of maps (this was the average number of participants at most events in the early days) was the black and white photograph. Offset printing (especially colour) was too expensive and technically very difficult for even keen organisers. To move one step further, the sport had to reach a higher level: increase the number of participants in events, create international relations, form regional and continental organisations.

The first colour orienteering map especially ground surveyed (field worked) for this sport was published in Norway in 1950.

In 1965, the Map Committee of the IOF was formed (the first meeting was held in 1967, Zürich). All five members were cartographers (Jan Martin Larsen - Norway, Osmo Niemelä - Finland, Christer Palm - Sweden, Torkil Laursen - Denmark, Ernst Spiess – Switzerland). They all were orienteers.

The most important and urgent work of the committee was the specification of World Championship maps:

- The maps had to be new.
- The map had to show every detail of the terrain that could affect the route choice of the competitor.
- Most important was the accuracy and legibility: small and unimportant details had to be omitted.
- The maps of international events had to use the same specification.

Suggested scale was 1:25 000 or 1:20 000, the contour interval (equidistance) was 5 m (10 m or 2.5 m were also allowed depending on the terrain). (Table see next page).

**Base maps for orienteering maps**

Even if we access good and up to date base maps, mapmaking for orienteering requires a lot of time for ground survey, much more than in the case of any other ordinary (topographic like) maps. The classic topographers can spend less and less time on ground survey. They would use the interpretation of aerial photos, but this method is not suitable for orienteering maps.

Depending on the quality of the available base maps, the mapmakers regularly spend 20-30 hours on every square kilometre (foot o maps). Depending on the map scale of the other forms of orienteering the larger scale maps require much more time on every square kilometre (sprint maps), while smaller scale require less time: the mappers concentrate mostly on the track network (Ski o and MTBO maps).

The quality of the base maps considerably affects the time the mappers spend on the terrain. We can calculate the most effective method if different base maps are available, spend more money on buying or creating good base maps or spend more time with ground
survey. However, sometimes the time factor is also very important.

State topographic maps can be used as base maps of orienteering maps if the scale is appropriate. In many countries, the largest possible scale of state topographic maps is too small. Therefore, the orienteers are looking for alternative solutions in these countries.

The scale of Foot Orienteering maps is 1:15 000, which is used enlarged to 1:10 000 for older competitors or certain variations of Foot Orienteering including Relays. The smallest possible scale of base maps that can be appropriate for orienteering mapping is 1:10 000 or even better 1:5 000. In many countries, these scales are not available for all parts of the country (especially not for the forest areas, which are commonly used for orienteering events).

Base maps with smaller scales (1:20 000) can be used for the other orienteering disciplines of Ski-O and MTBO. The competitors in Ski Orienteering and Mountain bike Orienteering events use only the path/track system, so the accuracy of off path elements is not so relevant. However the relief is always special importance in the route choice. Some of the features that are represented in normal orienteering maps are left out if they are not visible from the paths/tracks.

The discipline of Trail Orienteering uses the map specification of the shortest form of Foot Orienteering, called Sprint Orienteering.

Sprint Orienteering was devised to be as media friendly as possible. It uses mostly urban or park areas, the courses are very short (12-15 minutes) and the number of features on the terrain is much higher than in normal forest areas. To represent such complex areas and

<table>
<thead>
<tr>
<th>Form of orienteering</th>
<th>The time of first World Championshi</th>
<th>Limitations on the map or in the event</th>
<th>New symbols, changes according to fooot o maps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot Orienteering</td>
<td>1966</td>
<td>There is a tendency to standardise not only the maps, but the terrain too (not to use extreme terrains at international events).</td>
<td></td>
</tr>
<tr>
<td>Sprint Orienteering (part of foot o)</td>
<td>2001</td>
<td>New venues: city, park. Due to the very large speed of the runners, the suitability of maps is crucial.</td>
<td>Different map standard: larger scale, more details. Some new symbols, especially special urban and park features.</td>
</tr>
<tr>
<td>Ski Orienteering</td>
<td>1975</td>
<td>Reduced content in the map: runnability is omitted. The skiers regularly ski on the tracks.</td>
<td>Classified track symbols.</td>
</tr>
<tr>
<td>Mountain bike Orienteering</td>
<td>2002</td>
<td>Reduced content in the map: runnability is omitted. The competitors mainly use the tracks, paths and roads.</td>
<td>Classified track and path symbols (based on the suitability).</td>
</tr>
<tr>
<td>Trail Orienteering</td>
<td>1999</td>
<td>It is necessary to take into account that the map has to look correct from sitting position.</td>
<td>Sprint maps are practically adequate.</td>
</tr>
</tbody>
</table>
make legible maps for very fast events, we need larger scales of 1:5 000 or 1:4 000 and a different set of specifications with more symbols in plan shape and fewer point symbols.

For sprint maps, the base maps could be cadastral maps (land ownership) of 1:1 000-1:5 000 scales or very large scale state topographic maps of 1:5 000. As these areas are mostly urban or park areas, we have a good chance that these areas have already been surveyed to very large scale topographic and cadastral maps. Nevertheless, we are in the same situation as with the other orienteering maps, the information represented in base maps is normally accurate enough, but most of the "orienteering" features are not represented on the base maps. To make these maps usable for sprint orienteering, we always have to concentrate on the legibility.

In some countries where state topographic and cadastral maps are not available in suitable scales, the orienteers are looking for alternatives. Aerial photos or orthophotos are commonly accessible in these countries and special services are offered for making stereo photogrammetric plots with detailed contour lines. In Scandinavia, some firms specialise in creating base maps for orienteering. Photogrammetry needs more time to make use of the digital revolution than map drawing and printing. Nowadays, all aerial photos are digitally sensed (they are only images). Analogue photos are no longer taken, which negatively affects the preparation of photogrammetric plots as base maps for orienteering.

Sometimes the combination of aerial photos (or orthophotos) and topographic maps can be an alternative, obtaining contour lines from state topographic maps and all other data from the aerial photos.

In special situations (in countries without previous orienteering activity and without publicly available state topographic maps), the satellite images of on line web applications and services (Google Earth/Map, MS Live, NASA World Wind) can be used especially where the largest resolution images are available.

Airborne laser scanning

Since 1994, a new airborne terrain modelling technology has been available to the surveying industry and to other professional users. The term Airborne Laser Scanning (ALS) evolved as the hardware utilised in the aircraft is a logical advancement of the Airborne Laser Profiles used primarily by the forestry industry for many years. Other titles attributed to the same piece of hardware include LIDAR (the term favoured in the United States), and Airborne Laser Terrain Mapper (ALTM), the brand name used by the major hardware manufacturer in this field.

Whichever term is adopted, this laser technology is offering an alternative to traditional photogrammetric acquisition, but this technology is not yet so widely used as photogrammetry.

Airborne laser scanning is a remote sensing technique that measures the round trip time of emitted laser pulses to determine the topography of the Earth's surface (an active sensor measures the distance from the sensor to the ground by which the laser beam is reflected). Airborne laser scanning is a rapidly growing technology that has initially been conceived for topographic mapping.

The distance data alone cannot give the ground position. Aircraft position is calculated with high accuracy using a combination of GPS data both on the aircraft and on the ground, and aircraft acceleration and three axial attitude data measured by a special unit. Furthermore, the direction data of the laser beam is measured in the sensor on board. This data is combined to calculate the three dimensional position on the ground.

One advantage of airborne laser scanning compared to classical photography is that laser scanners are not dependent on the sun as a
Advantages of laser airborne scanning for orienteering maps:
- Saving of time in the ground survey because of its availability without interruption and preciseness (in few countries only at the moment).
- Time consuming work to find suitable photogrammetric pictures and photogrammetric services are no longer necessary.
- Significantly reduced costs compared to photogrammetric base maps (if the raw data is already available).
- Combination with orthophotos is easy and this combination can dramatically reduce the time of ground survey.

One disadvantage of laser airborne scanning is that detailed contour relief of raw data could easily lead to an overcrowded and poorly generalised map image.

This disadvantage also applies to the users of photogrammetric plots, who also leave the original contour lines with every small bends and details that are not easily visible on the terrain for the competitors in running speed.

GPS in orienteering mapping

GPS (Global Positioning System) devices are more commonly used during ground survey. To enable the data to be used easily maps need to be "georeferenced". Orienteering maps are not regularly "georeferenced", which means that only very few of these maps were fitted to known projections and/or datum of the national or international mapping systems (datum, projection, etc.). Theoretically, the orienteering maps used the same projection/datum as the
original base maps, but as time went on and the old maps were updated, new areas were added with more and more small distortions and they were incorporated in the maps. Practically, if we try to use GPS measurements and fit them to the orienteering map we have to “georeference” the orienteering map first. The “unreferenced” orienteering maps were suitable for the events, because the inaccuracies were distributed on the whole area of the map and these failures practically did not affect the navigation of the competitors, who use only the orienteering map and compass on the terrain. Absolute positional accuracy is of little significance compared to relative accuracy and to the proper representation of the terrain shape and features. Coordinates are not indicated in orienteering maps and GPS does not have a role in classic orienteering (according to the competition rules, external help during the events is prohibited for the competitors).

The “georeferencing” of existing maps is a time consuming process and requires some technical knowledge. This explains why orienteers need experts to help the “georeferencing”. However, orienteers normally do not have enough money to use the service of these experts.

Even in the most developed countries, this process is going very slowly because the quality of old fashioned orienteering maps is still good enough for orienteers and the use of GPS devices has not reached the critical value yet.

The number of orienteering mapmakers does not increase. They may have less and less time for ground survey and using GPS may help them to make their work more efficient.

What are the main advantages of using GPS?

- They are definitely more accurate than traditional surveying techniques (pace counting, bearing).
- Absolute positions are very helpful to improve mapping and can save minimum 25% of the survey time.
- Easy to discover the base map errors and uncertainties.
- Sharing mapping work with non mappers: we can ask experienced orienteers to collaborate in measuring, and they may help to complete the base maps. This is especially useful on terrains that are frequently used for training, where the orienteering activities are continuous and orienteers regularly visit all parts of the terrain.

Differential GPS correction gives advantages (more precise measurements), but requires more skills (devices) and probably more investment. GPS could be more widespread in the near future when GPS chips will be built in mobile phones (which may help to reduce the price of more advanced GPS devices) and new systems (like the European Union’s Galileo) will be operating. For orienteering mapping, the real time differential correction is not essential, but post processing can be useful. Nevertheless, the general accuracy of semi professional GPS devices is already good enough for orienteering mapping if we are familiar with the system.

Professional orienteering mapmakers have a different approach to the GPS technology:

- A GPS device is used at an early stage of the ground survey to add more point and linear features; however, if we have a good base map, it is not very important whether we use GPS or not.
- A semi professional GPS receiver is used in the initial stage of mapping. The mapmaker covers the terrain with the GPS receiver, recording anything that looks worthy, adding extra data: paths, walls, all kinds of point and line features. Differential corrections can be used as post processing, and the data can be imported into the drawing programme. This enhanced map will be used as a base map for the ground survey.
- On line differential correction is used in the terrain with the orienteering map drawing software on a wearable PC,
Figure 2: GPS points and tracks to enrich the base map of the WOC 2005, Japan. (Courtesy of Hatori Kazushige)

with a sunlight readable screen. The main disadvantage of this hardware is not only the price, but the lack of long time lightweight power supply (mappers regularly spend 8-10 hours on the terrain).

However, more and more mapmakers who are not familiar with the GPS technology simply use it: although the devices are less and less expensive and the technology is more user friendly, its use still requires technical knowledge.

The accuracy of this method (based on the mapping project of the WOC 2005):

- 95% of measured points are within 2 m horizontally.
- 2 m is good reliability for mapping (if the error is greater than 5 m, the data should not be used for mapping).
- Altitude information is useless (no user friendly software to implement altitude information is yet available).
- Absolute positions are very helpful to improve mapping and to save 25% off the fieldwork time.

GPS is also used in the most important orienteering events to track the route of competitors during the races. On line or (nearly) real time solutions are already available, but the technology is too expensive and too complicated for every day use (tracking was used at WOC 2001 for the first time).

Mapmakers can use other instruments like laser range finders and clinometers in the terrain, but using these devices is not widespread and these devices have not affected
the process of mapmaking dramatically. Using these devices may increase the accuracy of terrain measurements or may speed up the time of measurement. For example, using laser range finders will speed up the process of distance measurement: the mapmaker does not have to walk the distance as in normal processes (pace counting or GPS measurement). These devices must be small enough and easily usable on the terrain even in difficult weather conditions.

**Drawing orienteering maps**

The small number of symbols in orienteering maps made it relatively easy to create formerly hand-drawn orienteering maps by computer. The first vector-based general graphic software for personal computers (Adobe Illustrator) and the first GIS software was released at the end of the 1980’s. These software products were not easily used by orienteering mappers. It was extremely difficult for non-professionals to draw all the symbols of the orienteering map specification using this software environment. A few orienteers mappers have worked with these programmes and have drawn some orienteering maps with this software, but it was found to be very time consuming.

Text is not an important feature of orienteering maps. Text elements are supplementary, but they do not really increase the usability of the maps for the competitors. This fact made it relatively profitable to create special orienteering map drawing software.

Hans Steinegger, a Swiss mapper/software engineer, released the first version of his OCAD software in 1988-89 and nowadays about 95-98% of orienteering maps all over the World are drawn with this software. At that time, the text handling features of the PC software were very limited due to the lack of standardisation. Only Windows 3.1 and later versions solved this problem at the beginning of the 1990’s.

OCAD became even more popular when scanners became easily affordable and were substituted for the less comfortable input device, the digitizing tablet.

OCAD is now the standard map production software and is used in more than 60 countries. and it is not only used for drawing orienteering maps. The professional version is able to create other types of maps and is able to handle GIS (geographic information system) files. The user friendly environment of the OCAD software makes map drawing relatively easy even for beginners who are not familiar with any type of computer software. In some countries, orienteering maps were the first type of maps created by computer methods exclusively.

Orienteering maps are good indicators of how the new cartographic techniques are easily applicable for non-professionals or how widely they are used in everyday situations. The map production technique changed dramatically at the beginning of the 1990’s.

In the early 1990’s orienteering maps were still hand-drawn products, but within a few years maps were drawn on a computer in every country.

The next milestone in the production of orienteering maps has not yet reached its conclusion. The development of colour printing technologies and the price reduction of good quality colour laser and ink jet printers made the colour printing technology more affordable. The number of offset printed maps is continuously decreasing and the number of non offset printed maps is increasing. The main factor of this change is not simply financial, but the opportunity to insert the latest updates in the maps and over print the courses. The mapmaker is also able to control the complete printing process.

It is clear however that the quality of spot colour offset printed maps will remain the standard for some while. Laser and ink jet colour printers are not yet able to render the thin contour lines of the orienteering maps. The continuous development of colour printing
technologies will continue and the quality of
digital printed maps can approximate the quality
of spot colour offset printed maps.

Sometimes the two methods are
combined: the maps are offset printed, but the
competition courses are overprinted by colour
printers (which makes the map sizes standardised to A4 or A3).

Results

New techniques are useful only when we
can improve the quality of our product or we can
make the mapmaking process faster or more
efficient. The generalisation of orienteering
maps is extremely important so as to make
competition maps as legible as possible at
running speed. It can be dangerous if the new
technologies encourage more and more detail to
be inserted on the map and clutter the base
maps. It may encourage the mapmakers to
transfer these new features from the base map
onto the final orienteering map.

The complex application of available
techniques can be the best approach.
Depending on the terrain and the available base
maps, the mapmakers have to collect all
available information and use the most relevant
ones.

However, the technologies themselves
are not enough, the generalisation process of
orienteering maps cannot be automated and
without orienteering practice this work cannot be
done at the proper level. It does not matter what
kind of future techniques will be invented,
making orienteering maps will remain the classic
task of the ground survey.

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